QUADREX

200

R.G.A.

MP MASTER

MA30270

G.A.B. 1248

PRELIMINARY

QUADREX 200
RESIDUAL GAS ANALYZER

MARCH 1984

TECHNICAL MANUAL

INFICON
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I am a user of the INFICON Quadrex 200 [Residual Gas Analyzer (RGA)] model:

Faraday Cup Electron Multiplier

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My name_____

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We also invite you to comment on the usefulness of this manual by answering questions below. In this way, you will be helping us continue to provide you with clear and accurate information. We thank you for your help.

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This addendum explains operation of new features for the Quadrex 200. Those features include:

- Data out of range warning indicators in the Table mode and total pressure display.
- Partial Pressure warning indicators in the Partial Pressure display mode.
- Peak Find and Interleaving indicators in all displays.

Data Warning Message Interpretation

The Table display provides a saturation warning for each channel. When a saturation problem exists, the VAL number for the affected channel is displayed in inverse video. This indicates one or more of the following:

The AMPS number is set too high.
The CAL factor is set too high.
EMULT voltage is set too high.

When the AMPS number or the EMULT voltage (or both) is set too high the SCU is operating at saturation. Multiplying a signal by too high of a CAL factor results in a VAL number beyond display capabilities.

Total Pressure Warning Interpretation

The Total Pressure display warns of minimum pressure by changing the numerical portion to inverse video. When this occurs the pressure reading is considered invalid data. This warning functions in all measurement modes.

Partial Pressure Warning Interpretation

An inverse video Partial Pressure indication warns of invalid data. This will occur when the Partial Pressure of an AMU varies out of the instrument's measurement range. Partial Pressure Warning can also occur when the instrument is performing an automatic gain adjustment to compensate for changes in the input signal.

Peak Find Indicator Interpretation

The Peak Find feature continuously tunes the Quadrex 200 for optimum peak amplitude. During a Peak Find period an inverse video P appears in the upper right corner of the display and the current display mode is momentarily frozen.

Interleaving Indicator Interpretation

The Interleaving feature allows the Quadrex 200 to perform measurements on the Table Mode channels while operating in another measurement mode. During an Interleaving period an inverse video I appears below the Peak Find indicator position and the current display is momentarily frozen.

THE QUADREX 200 RGA

The Quadrex 200 offers real time solutions to process problems using the most advanced software modes for residual gas analysis available today.

The Quadrex 200 is a 1-200 AMU instrument you can depend upon to maintain consistent vacuum conditions, to create higher process yield, and insure greater throughput. Its powerful microprocessor design, and extraordinary, built-in software gives process engineers and operators the instrument they need. Quadrex 200 is an "operator-friendly" instrument designed for all levels of technical personnel. And Quadrex 200 may also be interfaced via standard RS-232C or IEEE-488 to your system computer or controlled with remote relays.

With the Quadrex 200 RGA, you'll be able to precisely identify specific gas levels--desired and contaminant--inside your vacuum chamber. And be able to diagnose pumpdown problems such as leaks, outgassing and pump malfunctions as well.

There are two, major software features for your benefit in the Quadrex 200. The Partial Pressure mode, which permits true partial pressure calculations, is as sophisticated a number crunching routine as you want it to be.

The second exciting software addition is our Spectra Library which turns over a new page in fast, accurate residual gas analysis. It's pre-programmed with up to 34 spectra; you can enter six more yourself and display them. At the push of a button you'll see the reference spectra displayed with a current bargraph in split-screen format.

Quadrex 200 offers a choice of sensor heads to meet your process needs--Faraday cup with a detection limit of 5×10^{-11} torr, and electronmultiplier with a detection limit of 5×10^{-14} torr for more demanding applications.

Welcome to a new era in gas analysis.

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QUADREX 200 WARRANTY

All instruments manufactured by Inficon Leybold-Heraeus Inc. are warranted against defects in materials and workmanship for one year from date of shipment. Sensors, with the exception of filaments and electron multipliers, are warranted for one year from date of shipment. Consumables are not covered.

Inficon reserves the right to determine and will disallow claims for defects caused by purchaser's modification, abuse, misuse, excessive ambient temperatures or other abnormal conditions of operation. Sensor abuse includes, but is not limited to, vibration or mechanical shock. Sensor failures resulting from vacuum deposited materials and/or contaminants are not warranted.

Failure of MOS circuits due to static discharge caused by improper handling is not covered.

Inficon will repair or replace, at its option, Inficon manufactured products which prove to be defective during the warranty period provided they are returned to Inficon.

Special Notes: Inficon will not, for any reason, accept any sensor exhibiting any deposited material accumulation without prior notice describing the character, composition, and any precautionary handling considerations related thereto.

To maintain maximum sensitivity, Inficon's Electron Multiplier sensor must be shipped in the Shipping Housing IPN 012-225 and under vacuum.

Accessories marketed by, but not manufactured by, Inficon Leybold-Heraeus including but not limited to Hewlett Packard 7000 Series Graphics Plotters, are subject only to those warranty provisions as provided by said accessories manufacturer.

No other warranty is expressed or implied. Inficon is not liable for consequential damages.

CAUTION: To obtain optimum results in the use of the Quadrex 200, observe the following precautions:

1. Do not expose the Electron Multiplier sensor to atmospheric air when not in use. Store under vacuum or dry, inert gas. Air exposure causes loss of multiplier gain.

2. Do not operate the sensor in "dirty" vacuum systems. Sensor performance degrades rapidly in the presence of heavy concentrations of vapors from pump oils, greases, etc. Diffusion-pumped systems must be operated with cold traps.

3. Do not allow the sensor electrodes or insulators to become coated with materials which may be deposited during system operation.

WARNING: High voltage exists in the cables, the Operator's Console, and the Sensor Control Unit. DO NOT operate with the cables disconnected or with the Operator's Console or Sensor Control Unit uncovered (unless specifically indicated in the instructions).

SHIPPING INSTRUCTIONS

Before returning any instrument to Inficon Leybold-Heraeus for service, be sure to contact our service department (listed below) for a Return Material Authorization (RMA) Number. Items will not be accepted without an assigned RMA. They must also be properly packaged, insured, and shipped transportation charges prepaid to one of the service departments.

INFICON SERVICE DEPARTMENTS

DOUG SWARTZ

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PREFACE

The Quadrex 200 Manual is written for people who install, operate, and maintain the Quadrex 200 Residual Gas Analyzer. To be sure that you receive additional or updated technical information as it becomes available, please return the postaged-paid reply card in the front of the manual.

The purpose and contents of each section of this manual are listed below. Additional details are at the beginning of each individually numbered section.

Table of Contents

Quadrex 200 Specifications - Lists Quadrex 200 RGA specifications and available options.

Front Panel Description - Describes front panel controls with basic information on their use. Useful handy reference.

Section 1 - Initial Set-Up and Installation - contains the information needed to unpack, check out, and install the unit.

Section 2 - Operating the Quadrex 200 - defines messages displayed, describes functions, and includes operating procedures and selection of display modes.

Section 3 - Configuring and Adjusting the Quadrex 200 - includes detailed procedures which can be performed in the field by qualified personnel.

Section 4 - Theory and Interpretation - provides theoretical information on the gas analyzer sensor and information on interpreting the mass spectra.

Section 5 - Electronic Circuitry - This section contains information on the electronic circuitry and principles governing the Quadrex 200 RGA operation.

Section 6 - Troubleshooting - includes a troubleshooting checklist and routine service procedures that can be performed in the field by qualified personnel.

Section 7 - Options.

When reading the Quadrex 200 Manual, please pay particular attention to the NOTES, CAUTIONS, and WARNINGS found throughout this text. For our purposes they are defined as follows:

NOTES: Pertinent tidbits of information useful in achieving maximum instrument efficiency when followed.

CAUTIONS: Failure to heed these messages could result in damage to your instrument.

WARNINGS: The most important messages. Failure to heed could result in personal injury and/or serious damage to your instrument.

We invite you to comment on the usefulness and accuracy of this manual by filling out the reply card and returning it to us.

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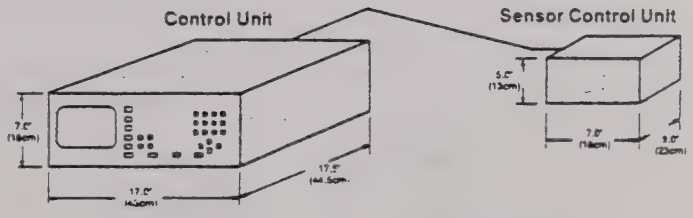
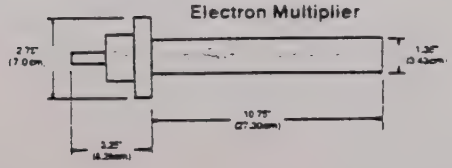
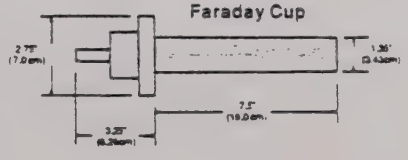
SPECIFICATIONS:

Data Display:	Built-in 18 cm (7") video monitor 7 data display formats: Analog—20 AMU segment of mass range Bar Graph—20, 40, 50, 100, or 200 AMU, programmable center mass Table—6 independent channels Leak Check—Single peak monitoring any AMU Bar Subtract—Subtract stored bar graph from active bar graph Spectra Library—Split-screen display of 34 preset and 6 user selected spectra versus real-time bar graph Partial Pressure Mode—6 preset and 6 user selected masses—displayed continuously Total pressure continuously displayed All displays include operating parameters and labeled axes.
Data Entry:	Front panel pushbuttons. RS-232C is standard. IEEE-488 and ten I/O relay inputs are optional.
Data Output:	RS-232C, composite video, digital plotter, and X-Y analog recorder outputs are standard. IEEE-488, 6-channel analog, and 6-channel relay outputs are optional.
Data Processing (internal):	Storage of up to 6 displays (1 per mode), automatic peak location, direct spectra subtraction, scan speed optimization, and self-test routine.
Mass Range:	1-200 AMU
Resolution:	$M/\Delta M \geq 2M$; $\geq M$ is peak width at 50% peak height and M is mass range.
Minimum Detectable Partial Pressure (MDPP):	Faraday Cup—$5x10^{-11}$ torr ($6.5x10^{-11}$mbar) (at N_2 per AVS standard 2.3) or 10 PPM, whichever is greater Electron Multiplier—$5x10^{-14}$ torr ($6.5x10^{-14}$mbar) (at N_2 per AVS standard 2.3) or 1 PPM, whichever is greater.
Scan Rates:	Selectable—very fast, fast, normal, slow, very slow. Actual scan speed is determined by gain range and displayed.
Gain Range:	10^{-7} through 10^{-13} amps in 12 increments
Temperatures:	Instrument—5° to 50°C (40° to 122°F) Sensor—350°C (662°F) max. bakeout (connector removed)
Sensor:	Filament—Burnout resistant thoria-coated iridium Mass Filter—factory-tested linearity and transmission characteristics insure superior control over three decades of pressure (from $5x10^{-5}$ to $5x10^{-8}$ torr).
Degas:	Front panel actuated, 2.5 minutes, self-timing, electron bombardment type.
Power:	100 watts, 100/120/240 Vac, +5/−10%, 50/60 Hz.
Shipping Weight:	Total System Shipping Weight—34 kg (75 lbs), approx., 2 cartons.
Options:	Digital Plotter/IEEE-488 I/O Communications X-Y Digital Plotter Analog Output Module Relay Output Module I/O Relay Module IPC-2 Pressure Converter Sensor Heating Jacket







OPERATOR'S CONSOLE PANEL DESCRIPTION

1.	MENU	Lists the available displays and modes for your selection.
2.	RESET	Dependent on the operating mode, it can: Restart the scan; Reinitialize the peak finder; Allow operation with stored program; and Clear memories.
3.	SAVE	Saves the present display in memory.
4.	MEM-X	Exchanges the present display with the display in memory.
5.	SCREEN	High visibility with scaled displays.
6.	COPY	Outputs data to hard copy device.
7.	RELAY	Activates or deactivates relays (if relay option is installed).
8.	DEGAS	Puts the sensor into the de-gas mode (for cleaning).
9.	EMULT	Turns on the Electron Multiplier voltage (if EM sensor is installed).
10.	EMIS	Turns the sensor on or off.
11.	OFF/ON	Controls power to the Quadrex.
12.	CURSOR	↑ ↓ ← → Moves cursor in indicated direction for numerical entries. Activates audio signals.
13.	E	Enter. Enters the numeric operating variables.
14.	C	Clear. Clears numbers entered on the screen and re-displays the value stored in memory.
15.	KEY PAD	Calculator type keypad. Number is entered on the screen at the cursor location.
16.	SCAN	↑ ↓ Increase ↑ or decrease ↓ the scan speed.
17.	GAIN	↑ ↓ Increases ↑ or decreases ↓ the current signal amplitude.

Section 1 of the Quadrex 200 Manual is divided into two parts; the first part contains the inspection and initial check procedures while the second part of this section contains the installation procedures. Once the initial checks are completed, you may go on to Installation or store the unit until you are ready to use it. For detailed explanations of operating procedures, please refer to Section 2. Following is a brief outline of information in this section:

INSPECTION AND INITIAL CHECK
- Unpacking and Inspection Procedures
- Inventory
- Initial Check Procedures
  - Operator's Console
  - Correct Operating Voltage
  - Initial Display
  - Display Modes
  - Sensor Control Unit

INSTALLATION
- Installing the Sensor
- ConFlat® Flanges
- Attaching the Sensor to the Vacuum Chamber
- Installing the Operator's Console and the Sensor Control Unit
- Connecting an Analog Recorder

CAUTION: DO NOT attempt to install the Quadrex 200 without reading this section. FAILURE TO FOLLOW THESE INSTALLATION INSTRUCTIONS MAY RESULT IN DAMAGE NOT COVERED BY WARRANTY.

WARNING: High voltage exists in the cables, the Operator's Console, and the Sensor Control Unit. DO NOT operate with the cables disconnected or with the Operator's Console or Sensor Control Unit uncovered (unless specifically indicated in the instructions).

UNPACKING AND INVENTORY

Unpacking and Inspection Procedures

1. If you haven't removed the Quadrex 200 from its shipping containers, do so now.

2. Carefully examine the unit for damage that may have occurred during shipping. This is especially important if you notice obvious rough handling on the outside of the cartons. REPORT ANY DAMAGE TO THE CARRIER AND TO INFICON, IMMEDIATELY.

3. DO NOT discard the packing materials until you have taken inventory and completed the check procedures.

4. Now that the unit is unpacked and inspected, you are ready to take inventory.

CAUTION: If you notice any discrepancies when carrying out these procedures, contact the Inficon service department immediately.

Inventory

Make sure that you have received all the necessary parts by checking the contents against this list:

DESCRIPTION	INFICON PART NO.
• Operator's Console	
Faraday Cup/Electron Multiplier	901-002-G1
Dimensions: 7"(18cm)Hx17"(43cm)Wx17½"(44.5cm)D	
Weight: 26 lbs. (11.8 kg)	
• Sensor Control Unit	
Faraday Cup	900-200-G4
Electron Multiplier	900-200-G3
Dimensions: 5"(13cm)Hx7"(18cm)Wx9"(23cm)D	
Weight: 7 lbs. (3.2kg)	
• Sensor	
Faraday Cup	019-100-G1
Electron Multiplier/Faraday Cup	019-101-G1
• Instruction Manual	074-072
• Power Cord	
7½'(280cm), 3 conductor	068-002
• Sensor Power Cable	
Faraday Cup	019-161-G1
Electron Multiplier/Faraday Cup	019-161-G2
• Mass Filter Control Cable	
Standard 15'(560cm)	017-121-G15
Optional 30'(1120cm)	017-121-G30
• Rack Mount Option Kit	017-031-G1
• Sensor Output Cable	901-007-G1

INITIAL CHECK PROCEDURES

You have already observed in checking out the inventory that the Quadrex 200 consists of three main parts: the Operator's Console, the Sensor Control Unit, and the Quadrupole Sensor. The sensor will not be used in these initial checks so you should set it aside in a safe place leaving the protective covers intact.

Operator's Console

The first step of checkout uses the Operator's Console and power cord only. Do not connect any other cables or devices to the unit for this check.

WARNING: **The instrument power source must share a common ground with the equipment to which the sensor is attached for normal performance. In some installations, it may be necessary to attach a heavy gauge ground lead from the equipment to a good earth ground point.**

Correct Operating Voltage

Before you plug in the power cord, check the line voltage selector card which is part of the power cord socket at the rear of the unit. To check this connection remove the power cord from the rear of the unit, slide the protective cover to the left, and pull the tab marked "fuse" out to swing the fuse holder open (see Figure 1.1).

Figure 1.1 Fuse Tab

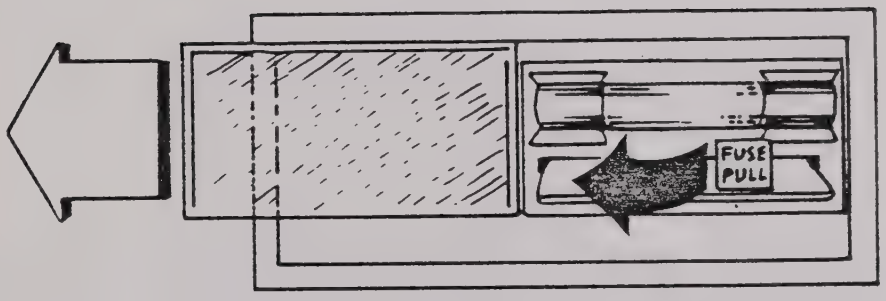


Figure 1.1 Fuse Tab

You can then reach a small circuit card to pull it out of the socket.

NOTE: Needle nosed pliers are very helpful when removing the circuit card.

Select your voltage (from the four voltages marked on the card) and re-insert the card with your voltage selection on the left side facing upward (see Figure 1.2).

Figure 1.2 Circuit Card

Check the line fuse at this time. On 100 or 120 volt units it should be 1.5 amps; on 220 and 240 volt units it should be .75 amps. Swing the fuseholder back into place, slide the protective cover over and plug in the line cord in the back of the unit. Make sure that the power switch on the lower right corner of the front panel is turned off and plug the power cord into an outlet of appropriate line voltage (normally 120 volts AC). Nothing should happen at this point.

WARNING: High voltage exists in the cables, the Operator's Console, and the Sensor Control Unit. DO NOT operate with the cables disconnected or with the Operator's Console or Sensor Control Unit uncovered (unless specifically indicated in the instructions).

Initial Display

Turn the POWER on by sliding the power switch left. The power supply pilot light should turn on and in approximately fifteen seconds a display should appear on the screen (Figure 1.3 - Initial Display). If the pilot light does not light or the display does not appear, check your power outlet and the main line fuse on the rear of the unit. If the pilot light comes on but no menu display appears, refer to Troubleshooting - Section 6.

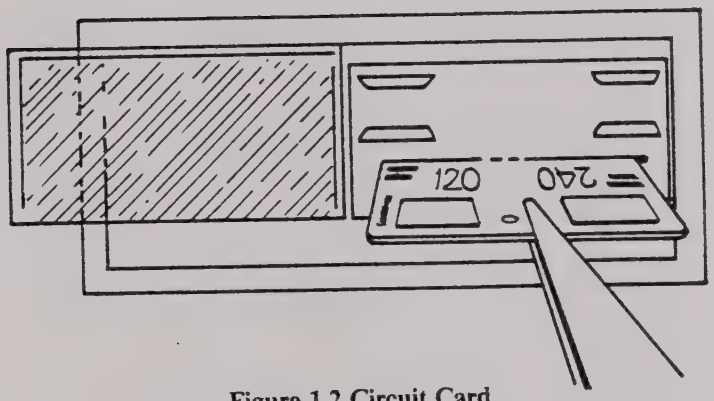


Figure 1.2 Circuit Card

NOTE: The Quadrex 200 memories retain the display mode in use at shutdown. This is the display mode identified by a cursor - (on the menu) when the power is turned on.

If after following the Troubleshooting check procedures you are still unable to get the proper display, contact the Inficon service department before proceeding.

Figure 1.3 Initial Display

The next step is to reset the memories to standard start-up conditions.

1. Turn off the POWER switch.
2. Press and hold the RESET button.
3. Turn on the POWER switch while still holding the RESET button.
4. After the MENU display appears, release the RESET button.

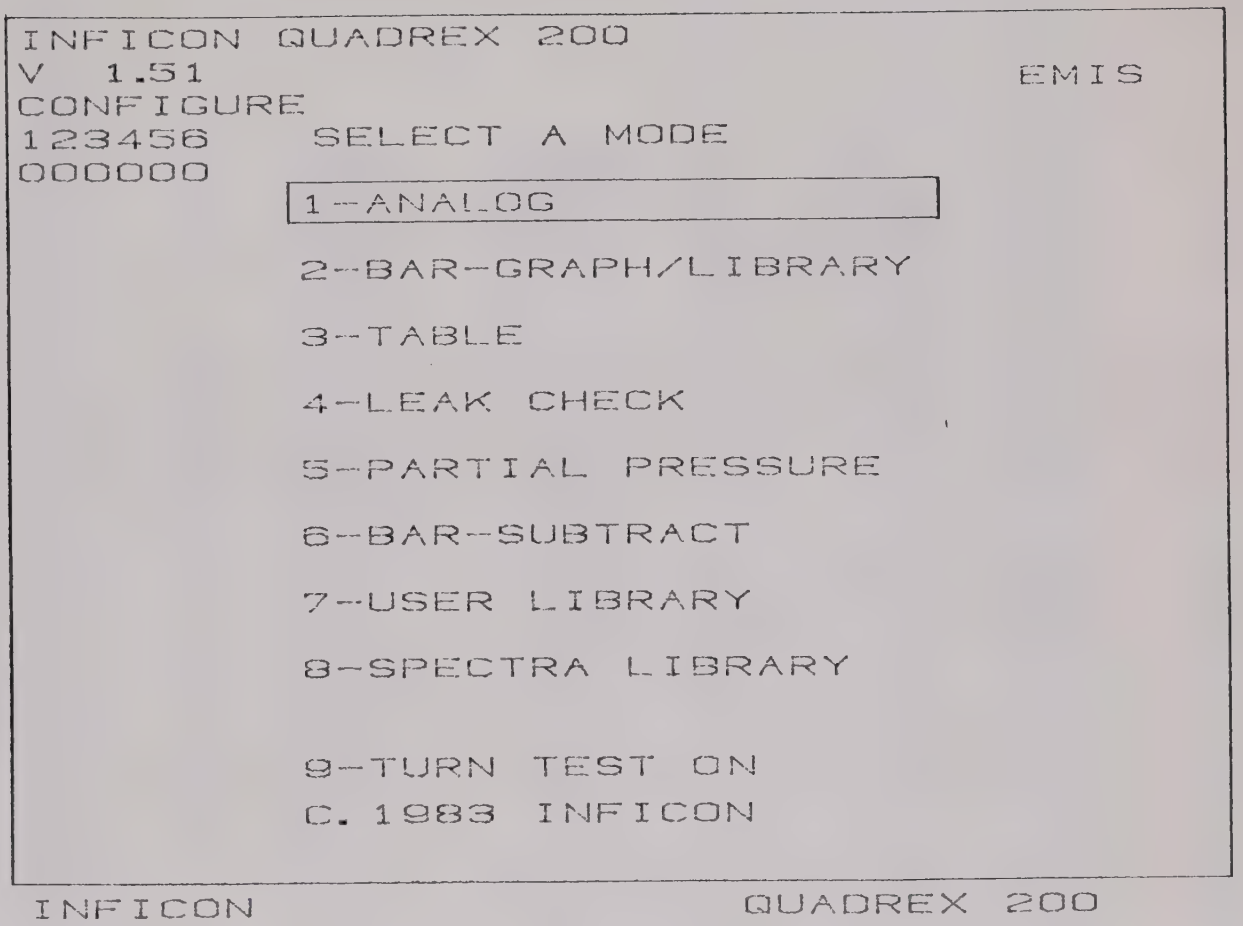


Figure 1.3 Initial Display

The words "PROGRAM LOSS" which appear on the screen are a warning that any previous programs stored in the Quadrex 200 memory have been erased. This warning message will disappear as soon as you change to another display screen.

The words "CABLE ERROR" appear on the screen and indicate that the cable to the Sensor Control Unit (SCU) is not connected. DISREGARD THIS WARNING FOR NOW.

Sensor Control Unit

If you have completed all of the above checks successfully, turn the POWER off and connect the Sensor Control Unit. For this procedure you will need to install:

a. The Mass Filter Control Cable (IPN 017-121-G15 or IPN 017-121-G30) which comes in 15' and 30' lengths and has 50 pin connectors at both ends. Plug it into the Mass Filter Control sockets on the rear of the Operator's Console and the Sensor Control Unit (SCU).

and

b. The Sensor Power Cable (IPN 017-122-G1 or IPN 017-122-G2) which has a black plastic connector at one end, 2 or 3 connectors [Emission, RF/dc, and Electron Multiplier (if EM unit ordered)] at the other end, and is approximately 3' long.

CAUTION: DO NOT plug the black connector into the sensor.

Connect the Emission and RF/dc connectors onto the Sensor Control Unit (the remaining connector for the EM voltage, if your unit is so equipped, need not be connected now - as this function will not be tested here).

Turn the POWER switch on. Observe the MENU display and place the unit in TEST mode by pressing key 6.9 When you press the key the flashing test indicator shows that you are in TEST mode. The message accompanying the test mode menu option should change to say "TURN TEST MODE OFF" indicating that pressing this numbered key will turn the test mode off. Try pressing the numbered key again to see that the test mode goes off and that the menu message changes. Be sure that you turn the test mode back on (shown by the flashing indicator).

With the test mode on, press key 1 to obtain the Analog Display. You should see a test pattern on the screen as shown in Figure 1.4. If you did not reset the memories at the beginning of the check procedure, you may get a different pattern because the instrument gain is different due to previous operations. The instrument gain is a combination of the vertical scale on the left hand side of the screen and the amps sensitivity figure in the upper left corner. To change the gain use the up or down arrow marked GAIN near the lower center of the front panel. Set the gain to the same figures that are shown in Figure 1.4.

Figure 1.4 Analog Display in Test Mode

Return to the menu and turn the test mode off by pressing key 9. Again select display 1 with key 1 and you should observe the Analog Display pattern with the test pattern being erased.

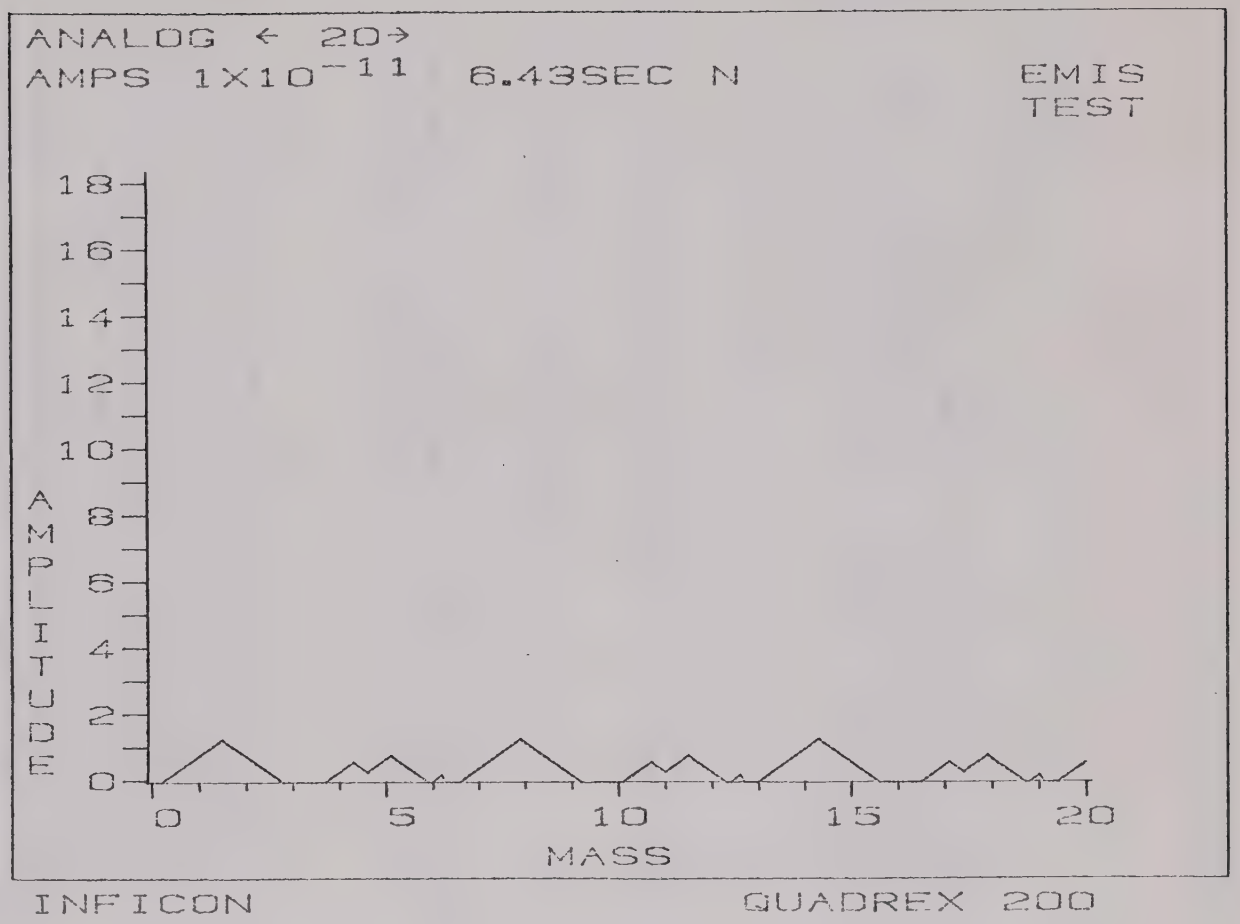


Figure 1.4 Analog Display in Test Mode

INSTALLATION

Installing the Sensor

One of two different types of sensors is furnished with the Quadrex 200. The two sensors are the Faraday Cup (FC) and the Faraday Cup/Electron Multiplier (EM) sensors. See Figure 1.6 to determine which type of sensor is used with your unit. (EM Multiplier message appears in upper left corner of screen in EM units.) Installation and handling of the two sensors is similar.

General Notes on Handling and Installation of Sensors.

- Do not touch any surface on the vacuum side of the sensor with the fingers. If it is necessary to touch any of these parts always wear clean linen or nylon laboratory gloves.

- Before installing the device on your vacuum system, check for any visible signs of loose or broken parts.

- Do not attempt to clean the sensor in any kind of solvent. Cleaning of the sensor requires disassembly. If you feel that the sensor is contaminated and needs cleaning, contact the Inficon service department for specific instructions.

ConFlat® Flanges

The sensor is installed on your vacuum system with a 2-3/4" OD ConFlat® flange. ConFlat® flanges, and similar compatible types made by other manufacturers, are widely used for attaching devices to ports on high vacuum systems. If you are familiar with the installation of this type of flange go on to page 1-10. If your system does not have a port with a compatible mating flange, an adapter will be necessary.

In order to install these flanges without having leaks it is important to follow the proper operating procedures. These flanges are sealed with a metal gasket and can be heated for bakeout to temperatures of 400°C or more without incurring leaks in the seal.

Assembling ConFlat® Flanges

When assembling a pair of ConFlat® flanges, it is important first of all that the sealing areas be clean and free of particulate matter. The sealing areas can be wiped with a laboratory towel using a clean solvent such as alcohol or acetone. A copper gasket is seated between the two flanges and it can also be cleaned in the same manner.

NOTE: **DO NOT TOUCH the gasket and flange faces with your fingers during the installation process.**

Install a copper gasket between the two flanges (Figure 1.5). ALWAYS USE A NEW GASKET, do not attempt to use gaskets more than once.

Figure 1.5 Gasket and Flange Assembly

Bring the two flanges together making sure that the gasket fits in the recess in both flanges. Flange faces should be parallel. If the gasket is properly seated it should not be possible to slide the two flanges laterally with respect to each other.

Install stainless steel bolts in the bolt holes of the flanges and tighten finger tight. If the flanges are to be baked, prelubricate the bolt threads with an anti-seize compound (FelPro® C 100 or equivalent).

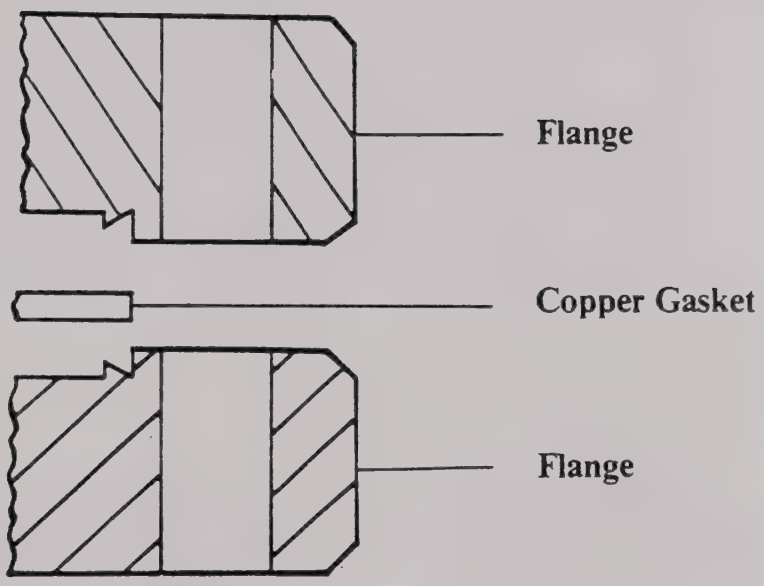


Figure 1.5 Gasket and Flange Assembly

CAUTION: Be careful not to get any of the anti-seize compound on the gaskets or the vacuum parts of the flange.

After the bolts have been finger tightened and the flange faces are parallel, tighten the bolts gradually and evenly in a criss-cross pattern until the flange faces are brought into contact all the way around.

Attaching the Sensor to the Vacuum Chamber

The sensor may be mounted in any position for convenience when attaching it to the vacuum vessel or chamber within which the measurements are to be made. However, you should avoid any magnetic fields greater than 2 gauss. It is important that the connection between the sensor and the vacuum chamber does not interfere with gas exchange to insure that the gas composition accurately reflects that existing in the vacuum chamber. But, if materials are evaporated or coatings are deposited in the vacuum chamber, you must protect the sensor against the deposition of these materials on its surfaces by installing a baffle or deflector. In systems which are baked, include the sensor in the bakeout zone or provide it with separate heaters. Dimensions of the Quadrupole sensors are shown in Figure 1.6 to assist in the planning of the installation.

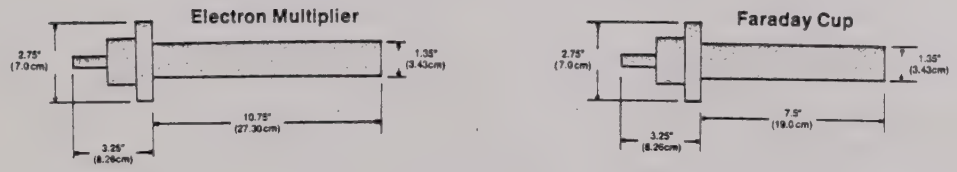


Figure 1.6 Sensor Dimension

Installing the Sensor Control Unit and the Operator's Console

The Sensor Control Unit contains the regulators and drivers which operate the sensor and the preamplifier which processes the output signals of the sensor. IT MUST BE LOCATED WITHIN 3 FEET OF THE SENSOR SO THAT THE SENSOR CABLES WILL REACH. A bracket is provided for mounting it to the sensor, but other mounting provisions can be made if necessary. The Sensor Control Unit should be mounted in an area where the ambient temperature does not exceed 122°F (50°C) and where there is free air circulation around the unit. You will also be able to obtain higher sensitivity from your instrument if you minimize vibration. Best performance will be achieved if the unit is not located close to major heat sources where it is subjected to wide temperature variations during operation.

Figure 1.7 Sensor Mounting

The Operator's Console may be located at any convenient spot within the length of the cable furnished. Standard cable options allow for distances of 15 and 30 feet from the Sensor Control Unit. The Operator's Console may be used on a table top or mounted on an instrument rack using

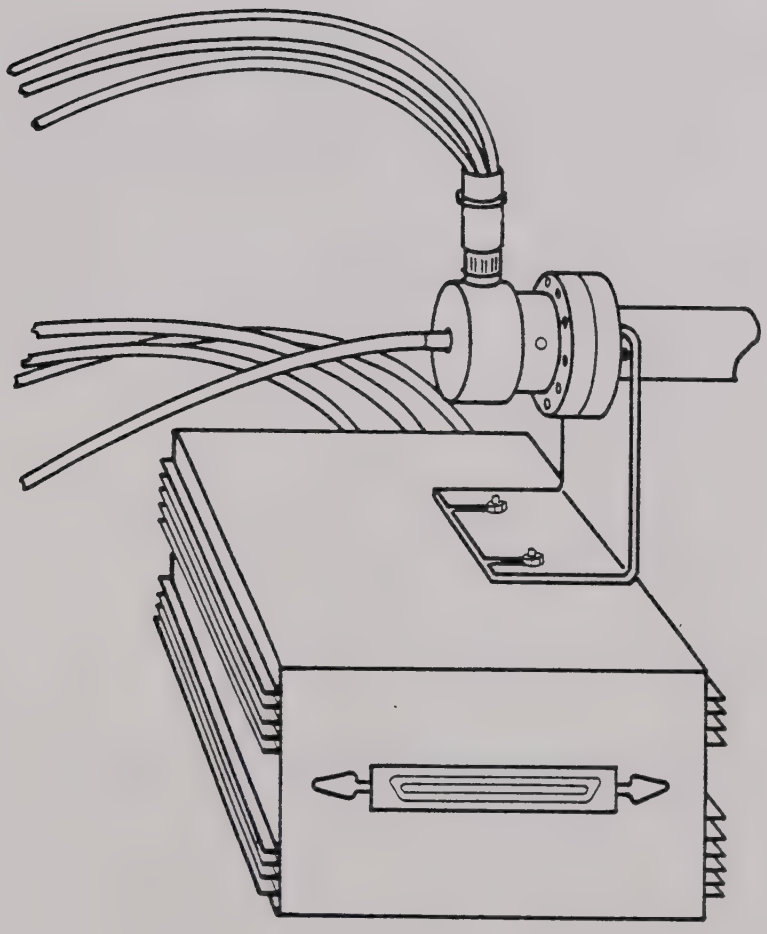


Figure 1.7 Sensor Mounting

the rack adapter kit. This unit should be mounted in an area where the ambient temperature does not exceed 122°F (50°C) and where there is a free flow of air around the unit. Avoid strong magnetic fields which may distort the display on the video screen.

Two electrical cables are required for connecting the sensor to the Sensor Control Unit. The small coaxial cable (IPN 017-123) carries the sensor output signal; it connects the central terminal on the end of the sensor to the amplifier input terminal on the Sensor Control Unit as shown in Figure 1.8. Sensor power is provided by another cable (IPN 017-122-G1 or IPN 017-122-G2) that has a large black connector which plugs into the sensor. (This cable is also described on pages ___ through ___.) If you have a Faraday Cup unit, this cable has only two connections to the Sensor Control Unit. With the EM unit, there is a third connector going to the EM power supply.

The Sensor Control Unit is connected to the Operator's Console with one cable, (Mass Filter Control Cable, IPN 017-121-G15 or IPN 017-121-G30) as shown in Figure 1.9.

Figure 1.8 Quadrex 200 Electrical Connections

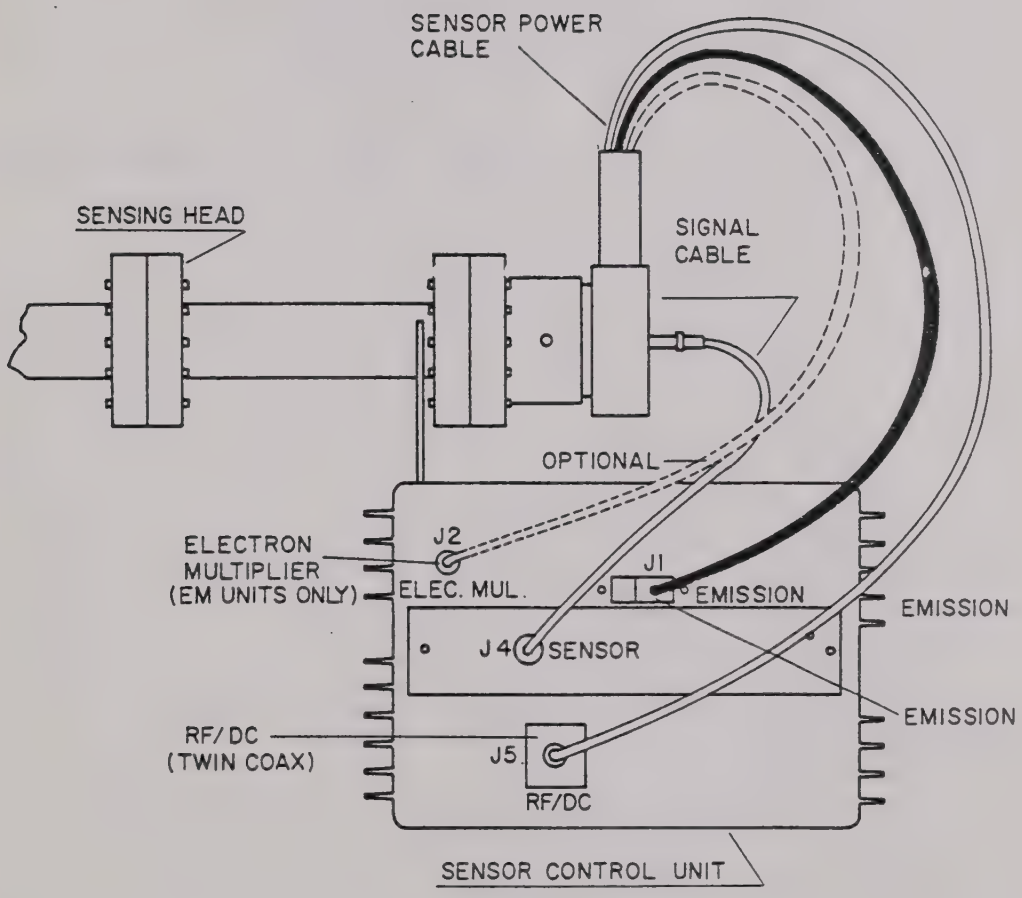


Figure 1.8 Quadrex 200 Electrical Connections

Power is supplied to the unit with the line cord which plugs into the rear of the Operator's Console.

WARNING: The instrument power source must share a common ground with the equipment to which the sensor is attached for normal performance. In some installations, it may be necessary to attach a heavy gauge ground lead from the equipment to a good earth ground point.

This instrument is grounded through the line cord of the instrument.

Figure 1.9 Cable Diagram

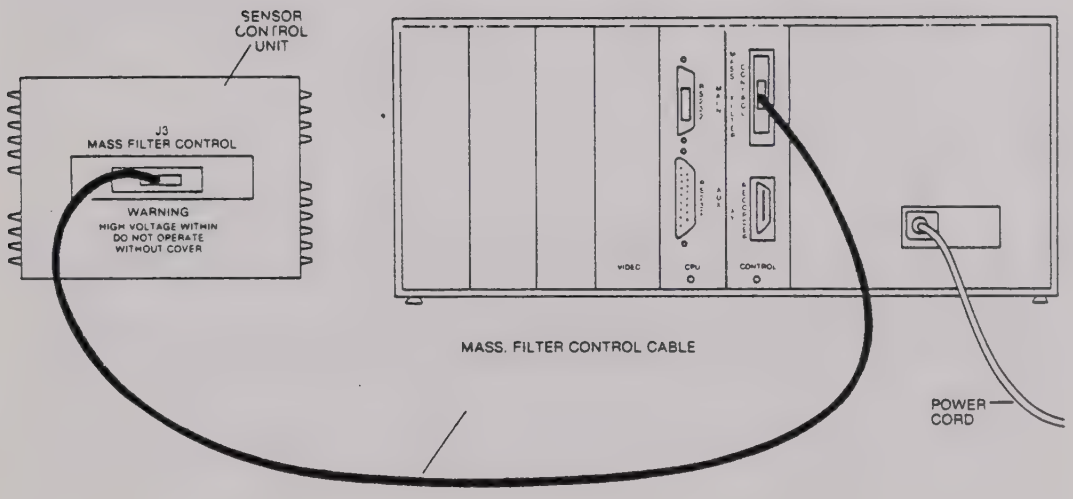


Figure 1.9 Cable Diagram

Connecting an Analog Recorder

The Quadrex 200 allows you to make permanent copies of the instrument output by connecting an analog recorder to the RECORDER output on the rear panel. The recorder output will produce a copy of the pictorial part of the screen display, but will not include any of the written information on the screen.

Other hard copy options are described in Section 7 - Options.

X-Y ANALOG RECORDER

Connector Definitions:

Pin	Function
1	Ground
2	Ground
3	$\overline{\text{PEN DOWN}}$ TTL
4	Y axis output analog
5	X axis output analog

Pen control is a TTL active output capable of sinking 2 TTL standard loads. The pen is down when the $\overline{\text{PEN DOWN}}$ line is active low.

The analog X & Y axis drive signals are 0 to +10 volt outputs having an output impedance of approximately 200 ohms. Current source capability is 5 MA at 10 volts.

This completes the installation of the Quadrex 200.

Section 2 is divided into three separate portions and is designed to aid you at different levels of experience with the instrument.

First you will find a New User's Guide, intended for a first time user, which will guide you through basic operation of the instrument. This guide starts with an introduction to the instrument control panel and guides you through a basic system operation. This is where you will be instructed in the mechanics of programming the instrument.

Next, you will be introduced to an Operational Guide, intended for the experienced user; this is a summary of operations.

The third portion entitled Quadrex 200 Functions provides detailed descriptions of all Quadrex 200 functions. As each function is discussed, you will be instructed on the purpose of the function, valid parameter entry, and operation. Use this section for more detailed information on a particular function or feature. Following is a brief outline of the information in this section:

NEW USER'S GUIDE
- Power-Up
- Changing Display Modes
- Using the Analog Display Mode
- Using the Bar-Graph Library Display Mode
- Using the Library Mode
- Using the Table Mode
- Using the Leak Check Mode
- Using the Partial Pressure Mode
- Using the Bar Subtract Mode
- Using the User Library
- Using the Spectra Library

OPERATIONAL GUIDE
- Start-Up
- Functions

QUADREX 200 FUNCTIONS
- Instrument Operation
- Electron Multiplier
- Start-Up Procedure
- Instrument Displays

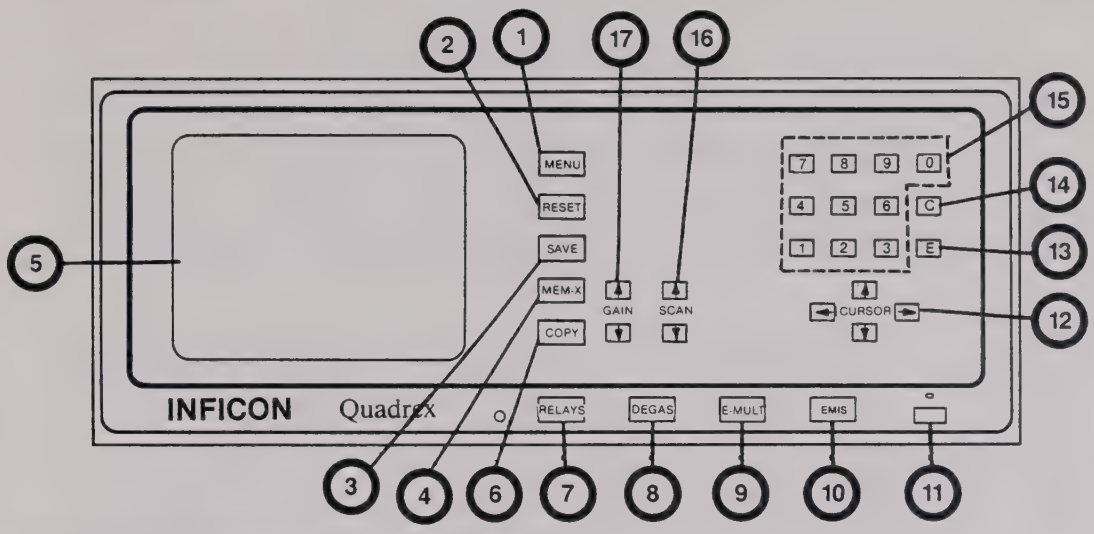
SECTION 2
OPERATING THE QUADREX 200

NEW USER'S GUIDE

The New User's Guide is a tutorial on the functions and use of the Quadrex 200. To follow the User's Guide, your system must be operational, with the sensor connected and adequate system vacuum (10^{-4} torr or better). Refer to Section 1 for instructions on Installing the sensor and cable connection.

Before you use the guide go to Figure 2.1 and review the key nomenclatures and their associated functions.

Figure 2.1 Front Panel Key Designations



OPERATOR'S CONSOLE PANEL DESCRIPTION

1. MENU — Lists the available displays and modes for your selection.
2. RESET — Dependent on the operating mode, it can: Restart the scan; Reinitialize the peak finder; Allow operation with stored program; and Clear memories.
3. SAVE — Saves the present display in memory.
4. MEM-X — Exchanges the present display with the display in memory.
5. SCREEN — High visibility with scaled displays.
6. COPY — Outputs data to hard copy device.
7. RELAY — Activates or deactivates relays (if relay option is installed).
8. DEGAS — Puts the sensor in the de-gas mode (for cleaning).
9. EMULT — Turns on the Electron Multiplier voltage (if EM sensor is installed).
10. EMIS — Turns the sensor on or off.
11. OFF/ON — Controls power to the Quadrex.
12. CURSOR — ↑ ↓ ← → Moves cursor in indicated direction for numerical entries.
13. E — Enter. Enters the numeric operating variables.
14. C — Clear. Clears numbers entered on the screen and re-displays the value stored in memory.
15. KEY PAD — Calculator type style keypad. Number is entered on the screen at the cursor location.
16. SCAN — ↑ ↓ Increases ↑ or decreases ↓ the scan speed.
17. GAIN — ↑ ↓ Increases ↑ or decreases ↓ the current signal amplitude.

Figure 2.1

1. Power-Up

Start the New User's Guide with the instrument power OFF.

For maximum clarity in following the New User's Guide, we recommend that you perform the power-on with reset as described below. However, you may simply turn the POWER on at this point.

To reset on power-up, press and hold the RESET button while you turn on instrument power. As you switch the POWER switch to ON, continue to hold the RESET button until the MENU display appears. (Refer to Fig. 2.1a).

The menu allows you to select various forms of displaying the information being measured by the instrument. Each of these displays is designed to be especially convenient for particular uses. We will discuss these uses below when each display is described in more detail. In this section, you will learn how to change display modes.

The words PROGRAM LOSS (or POWER LOSS) will be flashing in the upper right corner of the display. You will also see the RELAY (if you have a Relay Board installed) and EMIS warnings flashing and the cursor should identify the 1-ANALOG selection. If any other warning messages appear refer to the list of Warning Messages beginning on page 2-28, and correct the fault before proceeding with operation.

2. Changing Display Modes

Press the number "1" key on the front panel numerical key pad.

The instrument is now in the ANALOG mode (refer to Figure 2.2).

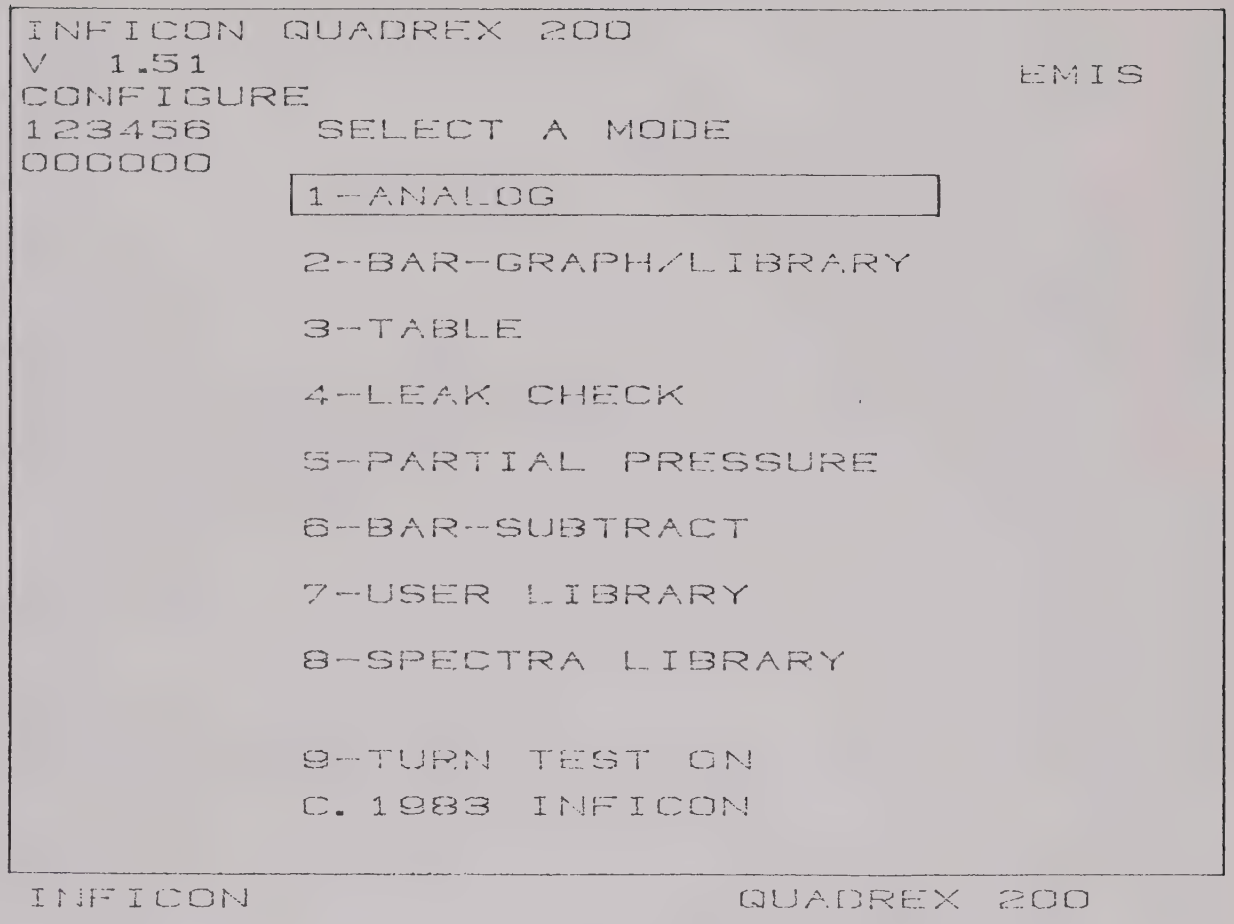


Figure 2.1a Initial Display

Figure 2.2 Analog Mode Display

Now press the MENU key on the instrument front panel.

You have returned the instrument to the MENU display mode. In order to change the display from one mode to another you must first press the MENU key to enter the MENU mode and then make a selection from 1 through 8 via the numerical key pad. (Selection number 9 is a TEST mode which will not be discussed in the New User's Guide. Refer to the QUADREX 200 FUNCTIONS section on Detailed Descriptions for the explanation.)

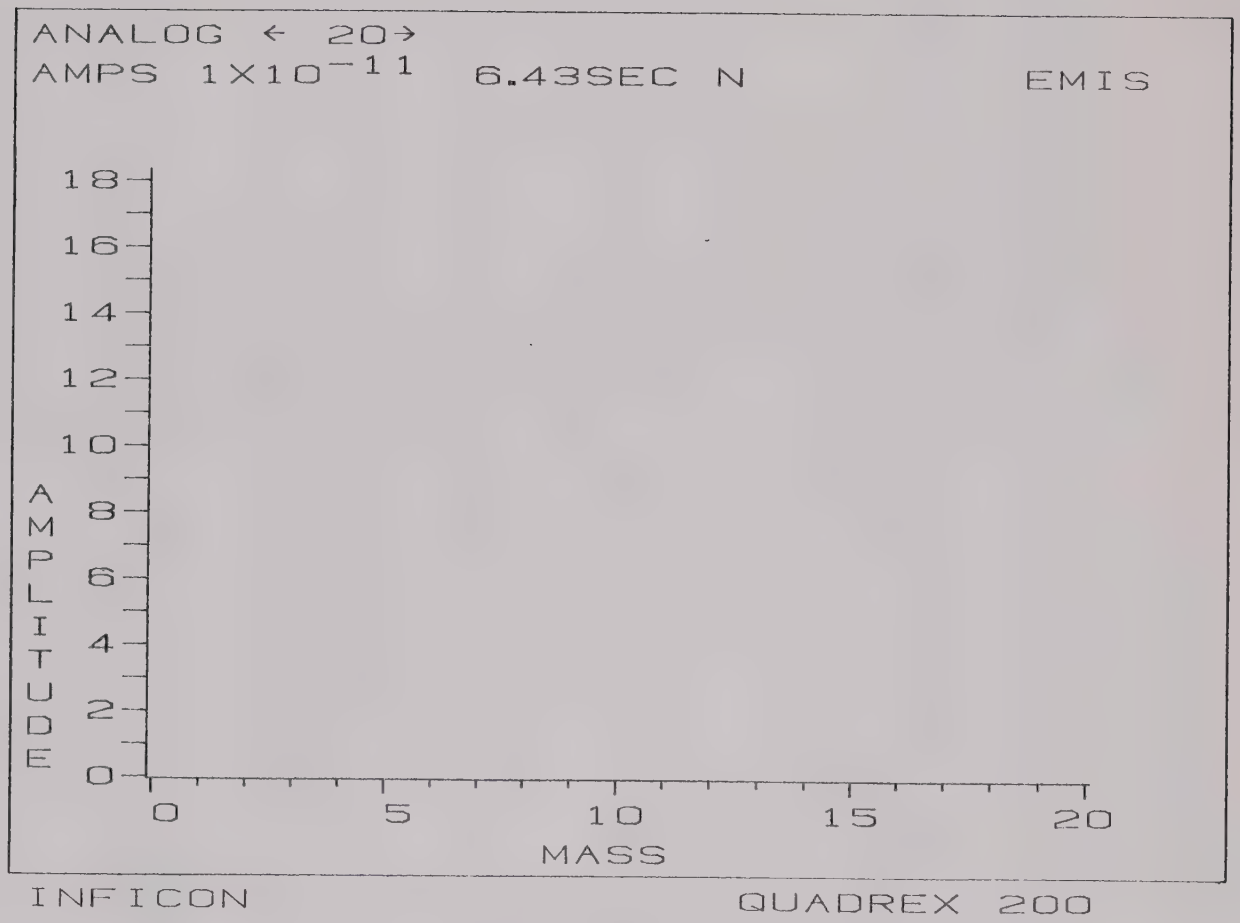


Figure 2.2 Analog Mode Display

The following paragraphs involve actual operation. Be sure to follow all CAUTIONS and NOTES.

CAUTION: In addition to being properly installed, the sensor must be in a vacuum of at least 10^{-4} torr for the EM head). If the vacuum is not sufficient, the unit will turn off operating voltages to the sensor to prevent damage.

3. Using the Analog Display

Press the number "1" key again. The ANALOG display mode will appear. If you RESET on power-up, the values for AMPS, SCAN TIME, SCAN SPEED, AMPLITUDE, and MASS are default values; if you did not RESET, the values from a previous operation are used.

Press the EMIS key to turn on the sensor head. The EMIS warning message should disappear and remain off. After 4 seconds, the pressure reading will appear in the upper right corner of the display.

If the instrument appears to be idle, it may be due to a RESET condition which is initiated when Emission is turned on for the first time. This RESET condition causes the instrument to pause at the end of the sweep to perform a peak find. This Peak Find calibrates the instrument to make sure that measurements are made on the highest point of the peak. This Peak Find may take several seconds.

If the EMIS warning comes on again, there is a fault in the system or insufficient vacuum. The instrument will display an additional message indicating the type of fault. Correct the problem before proceeding. Refer to the Troubleshooting Section, if necessary.

The Quadrex 200 is now in operation.

The analog display mode presents a reconstructed picture of a part of the mass spectrum as if it were obtained by a continuous sweep over this portion of the mass range. This display shows the actual shape of the mass peaks and is used where a detailed inspection of the peak shapes is necessary. For example, it will show if adjacent peaks are adequately separated. This display is also useful when making instrument adjustments and performing instrument maintenance.

a. SET THE ELECTRON MULTIPLIER VOLTAGE

For electron multiplier units only, you must set the voltage which you intend to use. To do this, move the cursor to the EMUL position. Set EMUL volts to 1500 for now. Set independently for each mode.

b. SET THE GAIN

Press the GAIN up key once, and then once again. Notice the values in the AMPLITUDE column change between 0 and 18 and 0 through 6. Also note that the AMPS, and SCAN time change. Continue pressing the GAIN up key and then the GAIN down key to see their effect. At some point, the gain should be sufficient that the instrument scan will show some peaks. Notice how increasing the gain makes the peaks larger, but also makes the peaks noisier. Notice also, that if you have set the gain too high, the large amplitude peaks begin to show noticeable signals at adjacent mass positions. The SCAN TIME value will change as GAIN is changed but not in a linear manner since this value depends on other parameters as well.

c. OBSERVE THE OPERATION

Assuming that you have just installed your sensor, you system will contain some amount of water vapor. With a center mass of 18 and a MASS width of 20 you should see a display similar to the one shown in Figure 2.3.

d. RESET THE SCAN

Notice a small marker which is moving along the horizontal MASS scale line. It starts at the left and scans to the right. This is the scanning marker.

Press the RESET key and notice that the marker stops and moves back to the left side of the scale and restarts. The marker is automatically reset when you change the GAIN or SCAN speed.

e. SELECT A SCAN WIDTH

The scan width can be set to 10, 20, and 40. The current width setting is shown at the top of the display between the two arrows < >. To change the scan width, press either the left or right CURSOR keys. Set the scan width to 20.

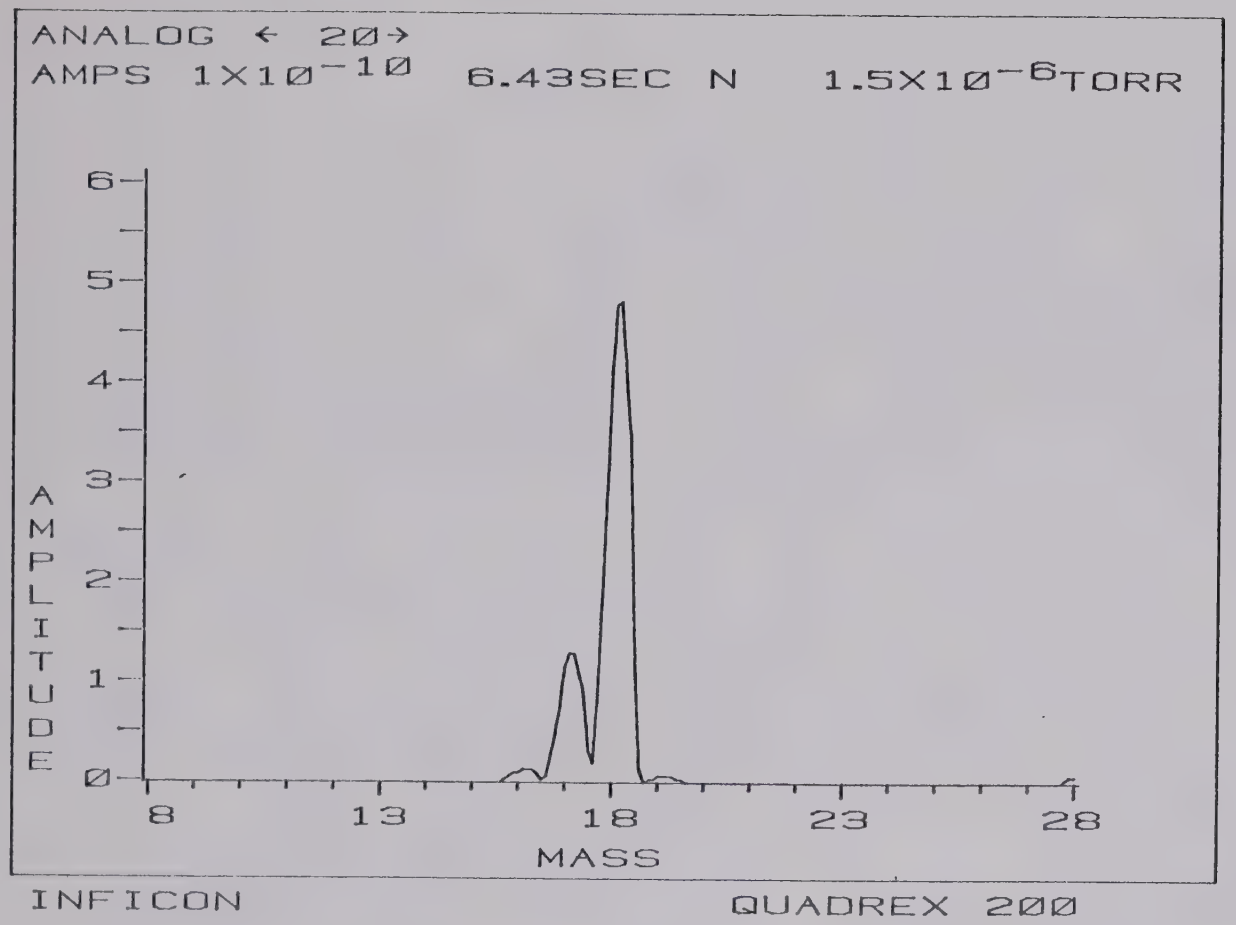


Figure 2.3 Analog/Water Spectra Display

f. SELECT A CENTER MASS

To select a new center MASS you must move the cursor to the center MASS position by pressing the CURSOR down key. The cursor will appear around the center MASS number (when you have an Electron Multiplier connected, the cursor will first appear beside the EMULT position*; press the CURSOR down key again).

Enter a new CENTER MASS number of 18; push the number keys in the order 1,5. To enter this new center mass number into memory press the "E" (enter) key. If the new entry is accepted the cursor will disappear; if it not accepted, the cursor will continue to flash along with the ENTRY ERROR warning message. If this occurs, you must press the "C" (clear) key to either retrieve the value in memory or retry an entry.

g. SET THE SCAN SPEED

Press the SCAN up and down keys and notice the SCAN SPEED changes in steps. Also notice that the displayed spectrum becomes noisier, more jagged looking, when the scan speeds are increased. Available SCAN speeds are VS (Very Slow), S (Slow), N (Normal), F (Fast), and VF (Very Fast).

h. SAVE THE DATA

Enter a new center mass, 33 for example. Once you have successfully entered the new value, press the SAVE key. This will store the display in MEM-X. Change the center mass to 18 again for comparison.

i. REVIEW THE DATA (MEM-X)

Press the MEM-X key and wait a couple of seconds. The display will change to inverse video and will show the display that you stored a moment ago. This is a status display of data recalled from the Quadrex memory. The center mass should be 33. Press the MEM-X key again and the display will change back to the standard dynamic display.

4. Using the Bar-Graph Library Mode

Now press the MENU key and the number "2" key to enter the BAR-GRAPH/LIB display mode (refer to Figure 2.4).

Figure 2.4 Bar-Graph/Library Display

BAR-GRAPH is the normal way that you should display the spectrum to determine what substances are present. This dislay is easy to interpret because it shows the essential information (mass number and corresponding peak height) in a clear and compact format. It is efficient because the instrument does not spend time tracing out the profiles of the peaks when peak shape information is not needed.

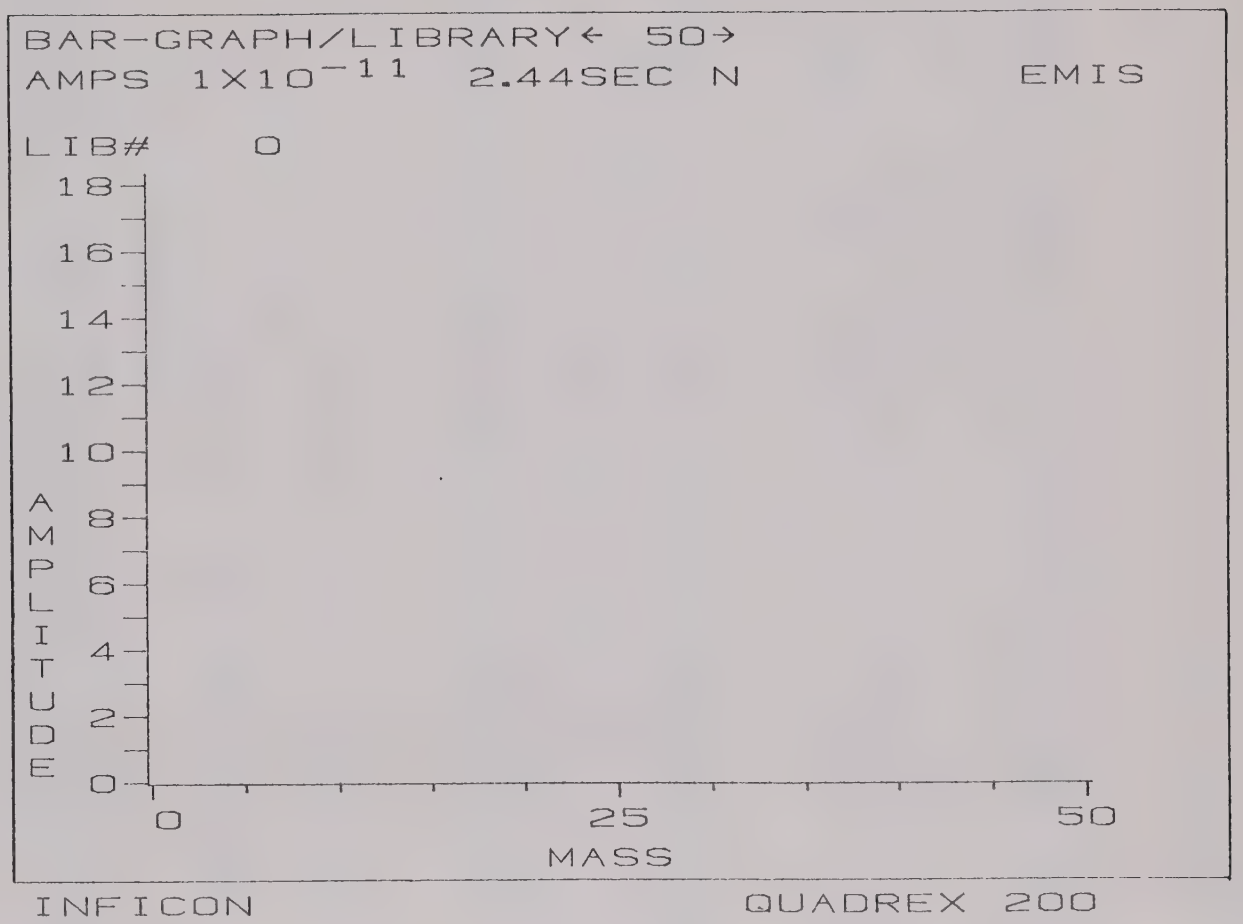


Figure 2.4 Bar Graph/Library Display

The LIBRARY function is an aid to identifying substances in the spectrum by comparing peak patterns of known substances with those produced by the instrument.

a. SELECT A SCAN WIDTH

Use the left and right CURSOR keys as you did in the Analog mode. The scan width can be set to 10, 20, 40, 50, 100, and 200 AMU. Set the scan width to 100.

b. SELECT A CENTER MASS

Use the CURSOR keys and keyboard as you did in the Analog mode. Enter a new center MASS of 50. This entry should be accepted and the cursor will disappear.

c. SET THE ELECTRON MULTIPLIER VOLTAGE

For electron multiplier units only, you must set the voltage which you intended to use. To do this, move the cursor to the EMUL position. Set EMUL volts to 1500 for now. Set independently for each mode.

d. SET THE GAIN

Use the GAIN up and down keys as you did in the Analog mode.

e. SET THE SCAN SPEED

Use the SCAN up and down keys as you did in the Analog mode.

f. OBSERVE THE OPERATION

Assuming that you just installed your sensor, your process chamber should contain some amount of water vapor. With a center mass of 50 and a MASS width of 100 you should see a display similar to the one show in Figure 2.5.

Figure 2.5 Bar-Graph Water Spectra

g. SAVE THE DATA

You can save the data as you did in Analog mode. Save it now for the BAR-SUBTRACT display described below.

h. REVIEW THE DATA

Press the MEM-X key and wait a couple of seconds. The display will change to inverse video and will show the display that you stored a moment ago.

5. Using the Library Mode

To select the LIBRARY mode you must enter a number in the LIB# position that is greater than 0 and less than or equal to 40. Selections 1

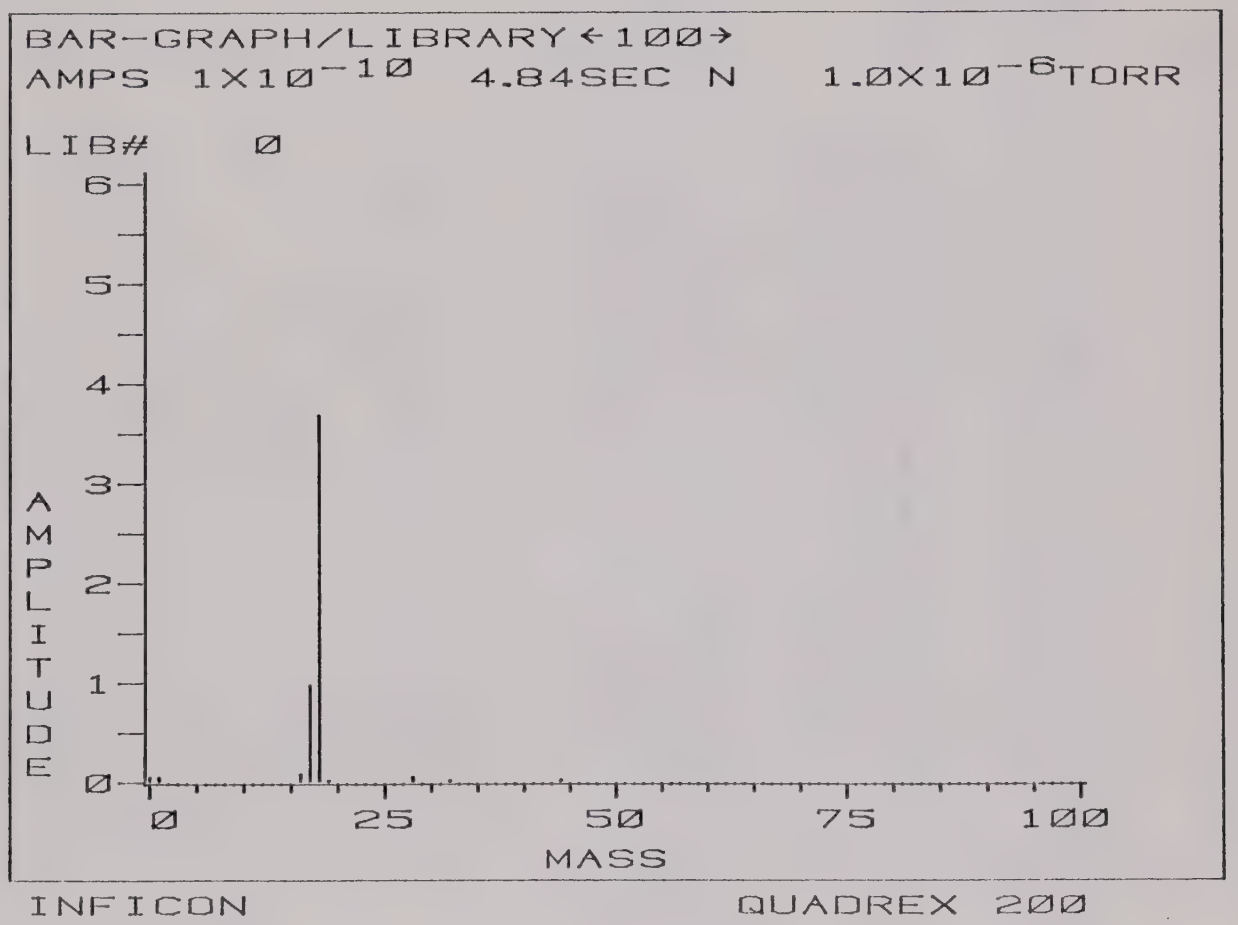


Figure 2.5 Bar Graph/Water Spectra Display

through 40 are listed on the SPECTRA LIBRARY display mode (MENU number 8). Press the CURSOR down key to position the cursor around the LIB# position, enter the number 11 (this selects the WATER spectrum).

NOTE: The AMU number of a given Library selection may fall outside of the mass width which you have selected. If this occurs, a RANGE warning will flash on the display. You must then change the center mass, mass width, or the Library selection.

The display is now a split screen display as shown in Figure 2.6. The upper portion of the display is a static Bar-Graph display of a normal WATER spectrum. Compare the Library spectrum with the actual spectrum; if your system contains water vapor you should see a similar pattern. You may find it necessary to increase the Gain to detect the water vapor spectrum.

Figure 2.6 Library Mode/Water Spectra

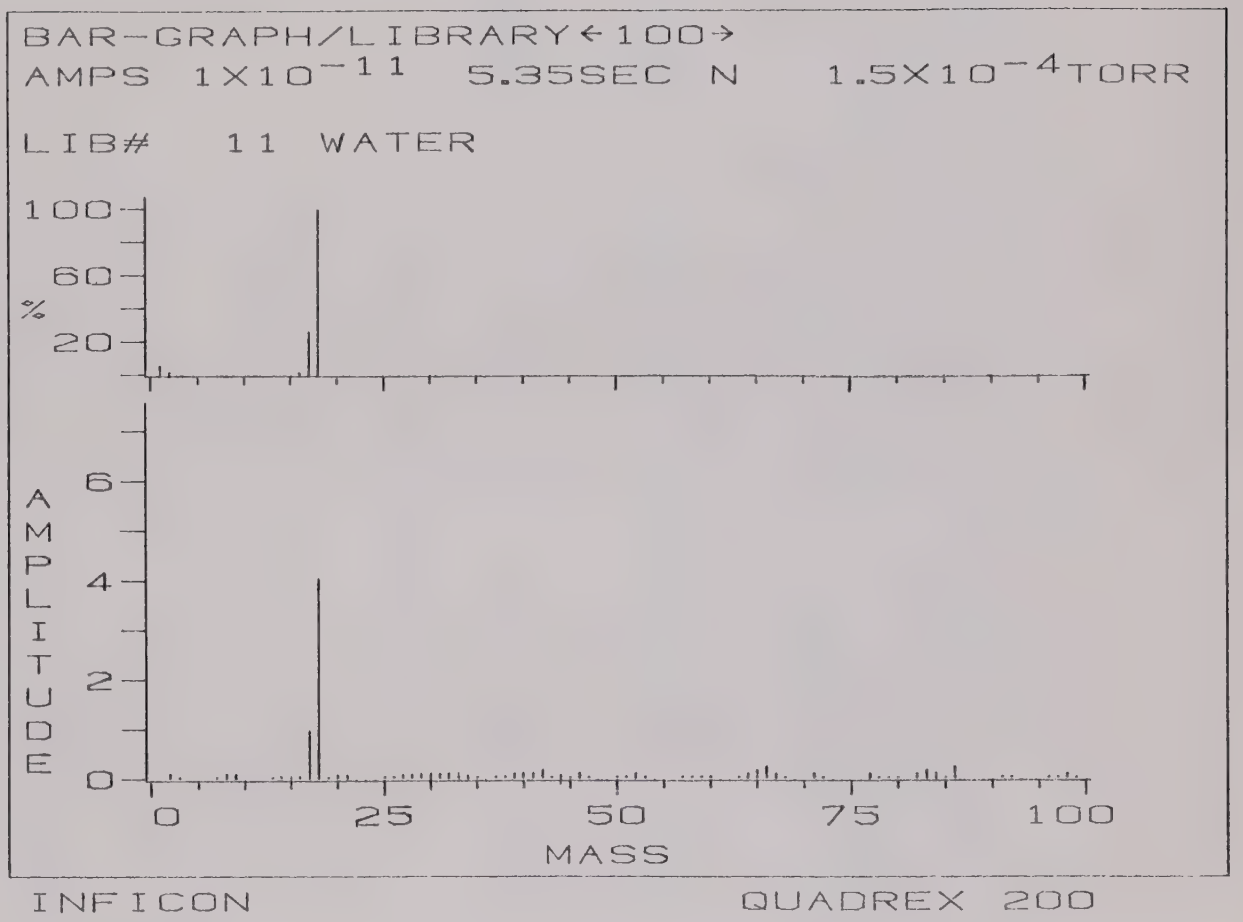


Figure 2.6 Library Mode/Water Spectra Display

a. CHANGE LIB# SELECTION

Changing the selection in LIB# may be accomplished in either of two methods. First, you may press a CURSOR down key and enter a new number using the numeric keypad. Or, you may prefer to step through the 40 selections in the spectra library. To use this method the cursor must not appear on the display and the number in the LIB# must be greater than zero. Press the "E" key to increment through the library; press the "C" key to decrement through the library. When either key is pressed, the LIB# will change.

Once you have made a LIB# selection, that same selection will be marked by an asterisk in the SPECTRA LIBRARY display mode. Press the MENU and "8" keys and find the asterisk positioned beside your selection.

6. Using the Table Mode

Press the MENU and "3" keys to enter the TABLE display mode as shown in Figure 2.7.

Figure 2.7 Table Mode Display

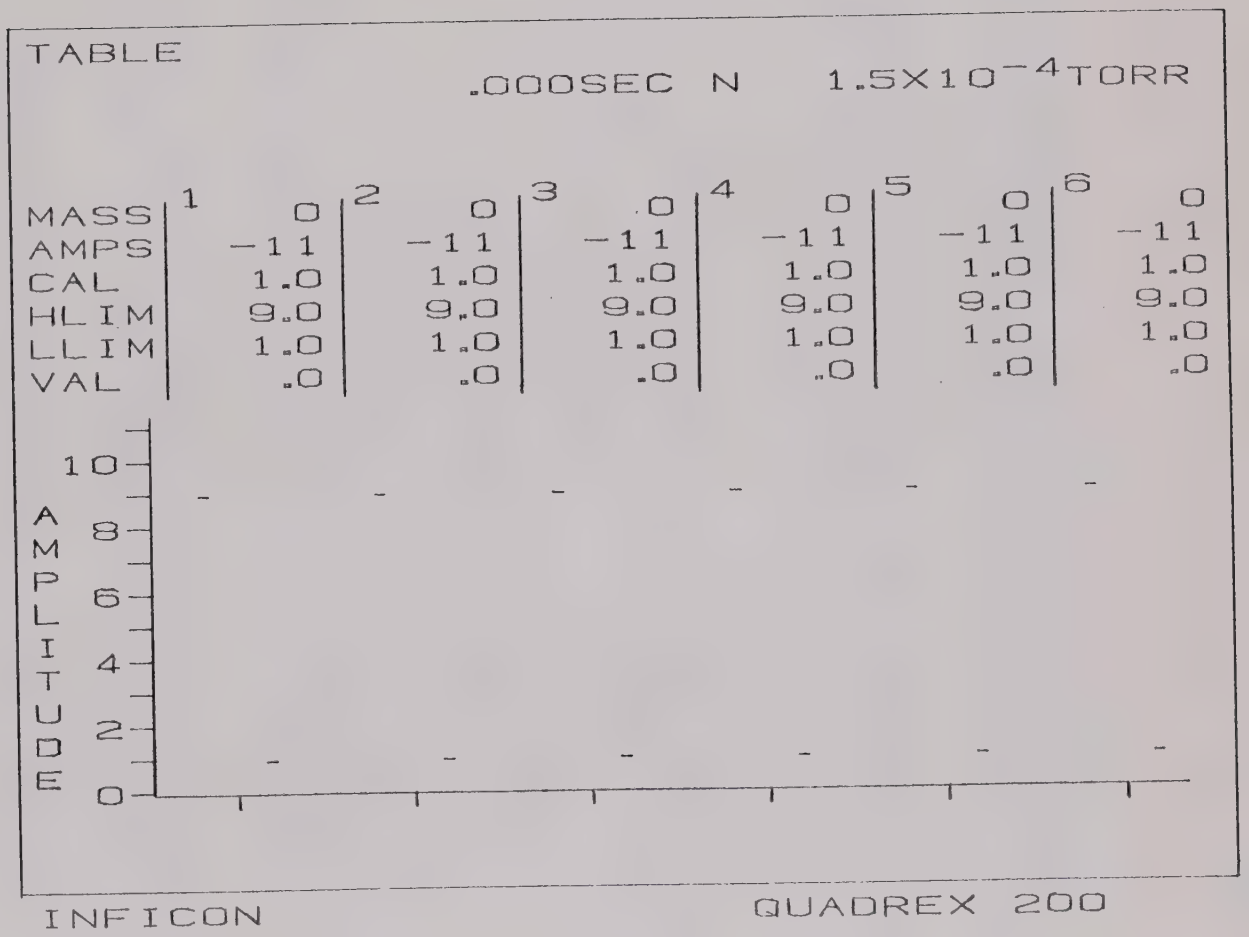


Figure 2.7 Table Mode Display

The TABLE display mode has six independent channels, each with its own operating commands. For each channel that you want to use, you must select a MASS number and an amplifier range (AMPS value). You can also enter a CAL factor, HLIM (high limit), and a LLIM (low limit).

The TABLE mode is useful when you do want to monitor just a few peaks in the spectrum and not make a general analysis. This mode permits you to display signals that are not of the same order of magnitude. It is also useful for alarm and control applications.

a. SET EM VOLTS

For electron multiplier units only, you must set the voltage which you intended to use. To do this, move the cursor to the EMUL position. Set EMUL volts to 1500 for now. Set independently for each mode.

b. SELECT CHANNEL PARAMETERS

NOTE: In the Table mode the CURSOR keys may be used to move the outline box vertically or horizontally through the table to any variable position.

Press any CURSOR key to obtain the cursor on the display. It will appear at the channel 1 AMU position (if you have an Electron Multiplier the cursor will first appear beside the EMULT position). You can select any whole number in the 1 through 200 range. Enter the number 18 and press the "E" key.

The cursor is now in the AMPS position. You can select and enter a new value between from 8 through 13 (corresponding to a scale factor of 10^{-8} to 10^{-13} amps). Use an AMPS value of 11 and move the cursor to the CAL position.

CAL accepts values from .0 through 9.9 (normally 1.0). Select .8 and move the cursor down to HLIM.

HLIM (high limit) may be set to any value from .0 through 9.9 that is equal to or greater than the LLIM. LLIM (low limit) works inversely of HLIM. When either HLIM or LLIM is changed, the associated bar moves to the AMPLITUDE of the new setting.

With the cursor positioned around the HLIM value, enter 10.0. As you press the "E" key notice the small bar in the left side of the channel column adjust accordingly.

LLIM (low limit) may now be set to any value from .0 through 9.9 that is less than or equal to the HLIM. Set the LLIM to 1.0. As you press the "E" key the small bar on the right side of channel column adjusts accordingly.

All remaining channels may be modified in the same manner.

c. SET THE SCAN SPEED

Use the SCAN up and down keys as you did in the Analog mode.

d. OBSERVE THE OPERATION

Assuming that you just installed your sensor, your process chamber should contain some amount of water vapor. You should see a display similar to the one shown in Figure 2.8. Note that the display contains both graphical and numerical information.

Figure 2.8 Table Display - Water Spectra

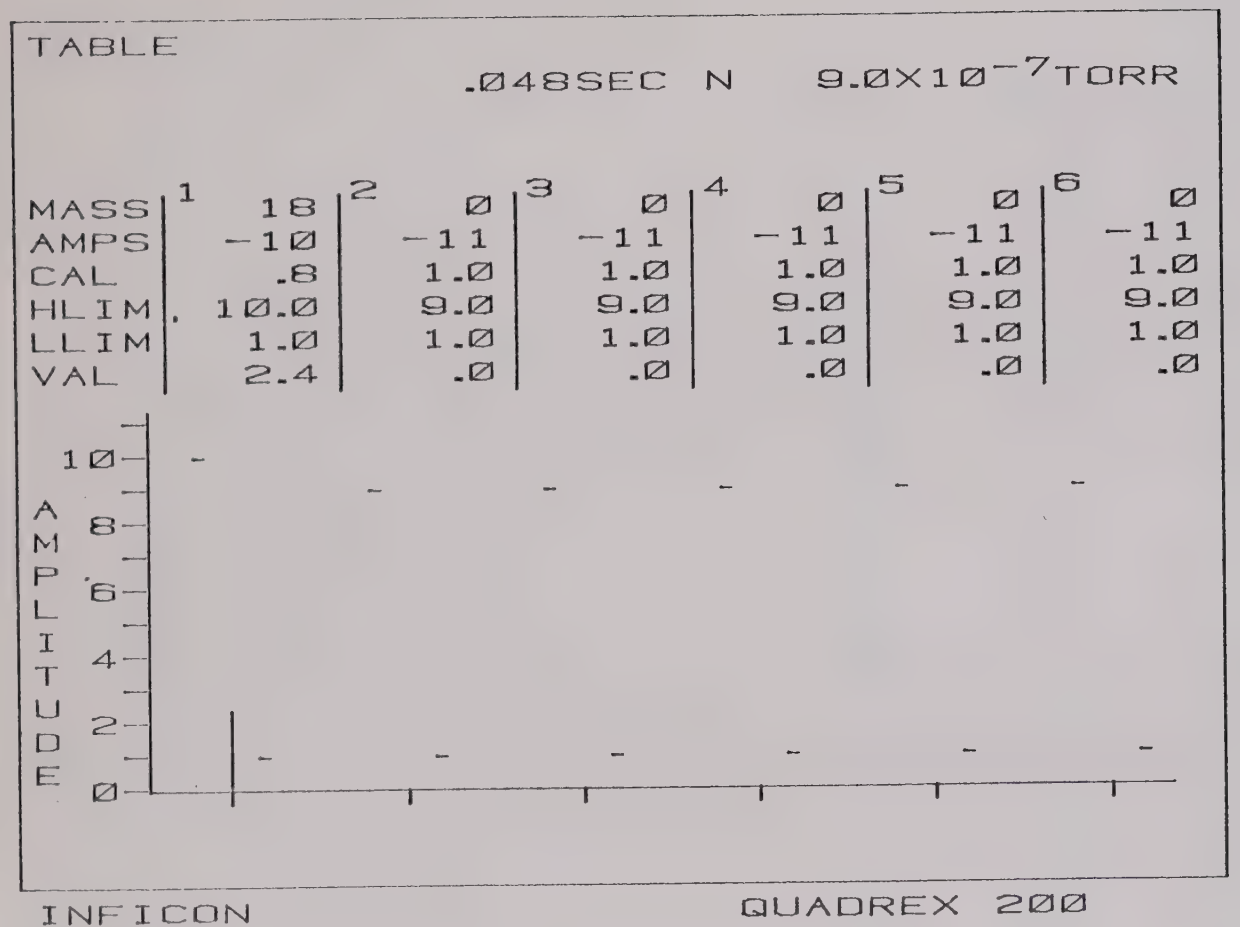


Figure 2.8 Table/Water Spectra Display

e. SAVE THE DATA

Enter a mass for channel 2, 50 for example. Once you have successfully entered the new value, press the SAVE key. This will store the display in MEM-X. CHANGE the mass for channel 2 for comparison.

f. REVIEW THE DATA (MEM-X)

Press the MEM-X key and wait a couple of seconds. The display will change to inverse video and will show the display what you stored a moment ago. This is a static display of data recalled from Quadrex memory. Channel 2 should have a mass number of 50. Press the MEM-X key again and the display will change back to the standard dynamic display.

7. Using the Leak Check Mode

Press the MENU and "4" keys to enter the LEAK CHECK display mode.

Figure 2.9 Leak Check Display

The Leak Check mode is used to monitor a single mass to watch for changes. This function is useful for leak detection when you are monitoring a mass corresponding to the tracer gas that you are using. You can instead watch for the disappearance of the gas source that you want to get rid of.

a. SELECT A MASS

Using the CURSOR down key, position the cursor MASS number. Once the number is outlined you may enter a new number in the 1 through 200 AMU range. Enter a new MASS number of 4. This entry should be accepted and the cursor will disappear.

b. SET THE AUDIBLE ALARM

The alarm is used to signal you in the event that the mass selected above is detected. Above the AMPLITUDE scale appears the alarm indicator "OFF< >LOUD".

To set the alarm volume, press the CURSOR right arrow to increase volume and the left arrow to decrease volume. As the volume is increased, up to three dashes will appear between the arrows. One dash indicates low volume, two dashes indicate medium, and three dashes indicate loud volume. When there are no dashes between the arrows the alarm is disabled. Set the volume to medium.

c. SET THE GAIN

Use the GAIN up and down keys as you did in the Analog mode.

d. SET THE SCAN SPEED

Use the SCAN up and down keys as you did in the Analog mode.

e. OBSERVE THE OPERATION

The LEAK CHECK mode is designed to aid you in locating a leak in the process chamber. To observe this operation, enter the MASS number of a mass which is in your process chamber (Bar-Graph mode may be used to determine an appropriate mass number). If the mass which you entered is detected in the Leak Check mode an alarm will sound. (Refer to Figure 2.9a).

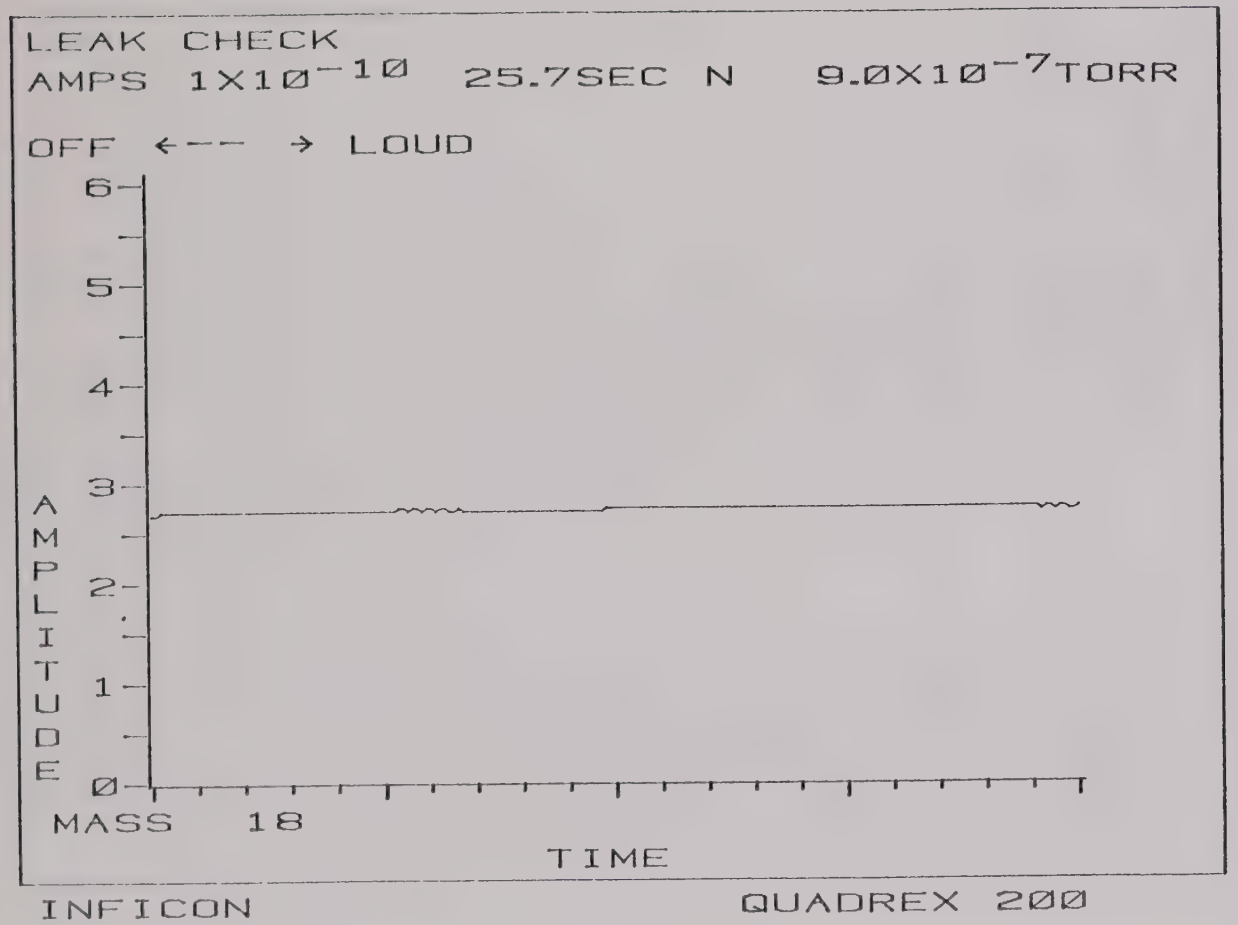


Figure 2.9a Leak Check at Mass 18

f. SAVE THE DATA

You can save the display by pressing the SAVE key. This will store the display in MEM-X.

g. REVIEW THE DATA (MEM-X)

Press the MEM-X key and wait a couple of seconds. The display will change to inverse video and will show the display that you stored a moment ago. This is a static display of data recalled from the Quadrex memory. Press the MEM-X key again and the display will change back to the standard dynamic display.

8. Using the Partial Pressure Mode

Press the MENU and "5" keys to enter the PARTIAL PRESSURE display mode (refer to Figure 2.10).

Figure 2.10 Partial Pressure Display

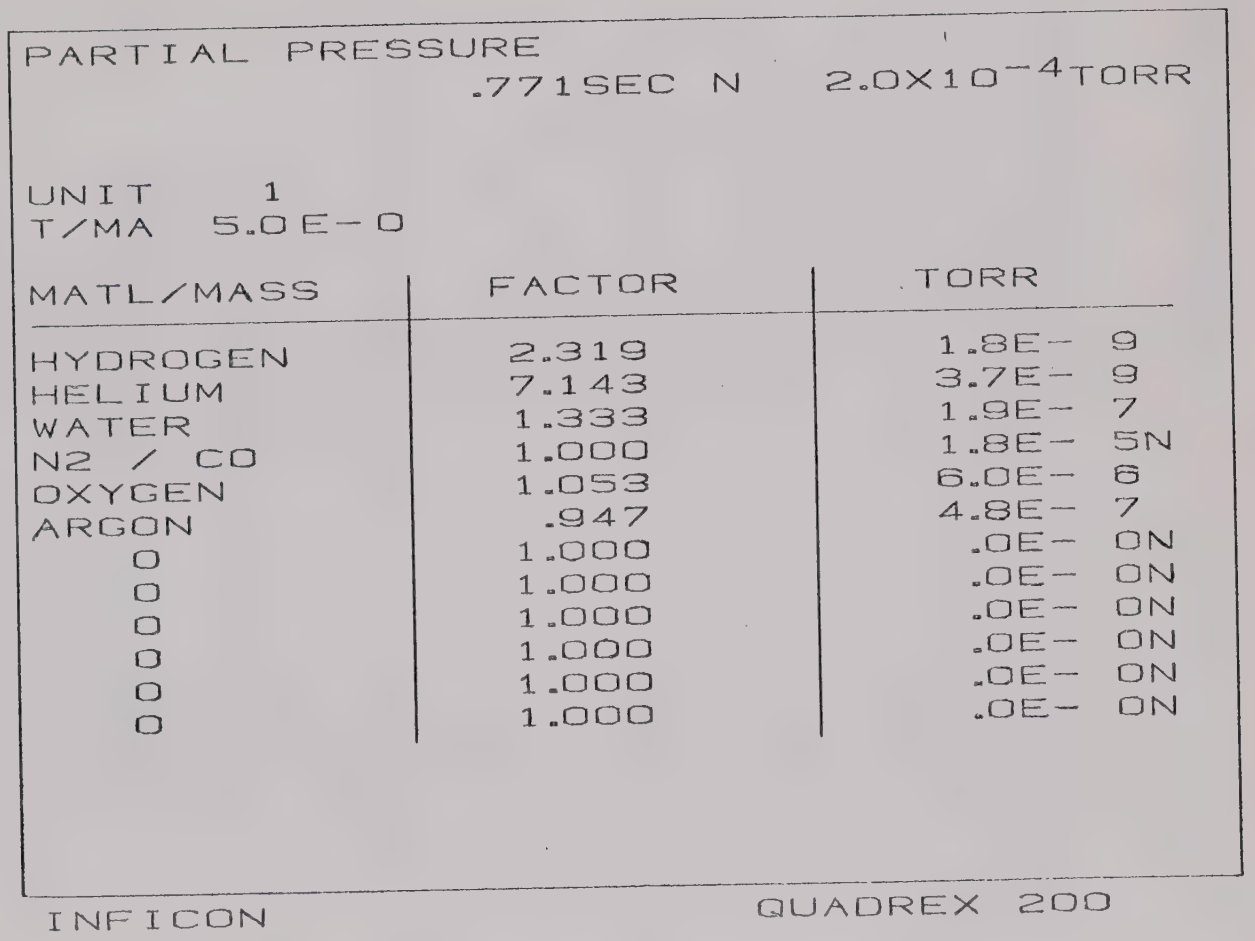


Figure 2.10 Partial Pressure Display

Partial pressure mode allows you to read the actual partial pressures of known substances directly on the screen. The values displayed are computed by the Quadrex using calibration factors and the measured amplitude of a specific peak for each substance. This display is useful when quantitative results are required. The Partial Pressure display contains only numerical information.

a. SET THE SCAN SPEED

Use the SCAN up and down keys as you did in the Analog mode.

b. SELECT THE UNIT OF MEASUREMENT

The partial pressure may be measured in one of three modes. To select a new unit of measurement, move the cursor to the UNIT position and enter 1 for torr, 2 for mbar, or 3 for pascal.

c. SELECT THE SENSOR SENSITIVITY FACTOR

NOTE: Typical value for a faraday cup sensor is 5.0^{-0}

Enger a two digit number (i.e. 50- the decimal point will automatically be entered). Once the two digits are entered, the cursor will move to the exponent position. Next, enter the exponent - 0 for faraday cup.

NOTE: When using the EM sensor the sensitivity value will vary with the EM voltage used. Refer to page 4-19 for EM value determinations.

NOTE: There are six factory pre-selected masses with appropriate factors for true partial pressures. These values are displayed in the last column.

d. SELECT A MATERIAL/MASS

Move the cursor to the first user entry position in the MATL/MASS column. You can select any mass value from 1 through 200. If you enter a mass number the cursor will move down to the next MATL/MASS position. Select additional masses or step the cursor through the list with the CURSOR down key.

e. SELECT A FACTOR

Move the cursor to the top of the FACTOR column. You may select a FACTOR value of four digits and the decimal point will automatically be entered. When a Nitrogen equivalent (factor of 1.000) is selected, an "N" will appear beside the Partial Pressure reading for that mass. For determination of the factor values, see page 4-19.

f. OBSERVE THE OPERATION

Assuming that you just installed your sensor, your process chamber should contain some amount of water vapor. You should be able to see a partial pressure reading for water vapor.

g. SAVE THE DATA

Once you have successfully measured the Partial Pressures in your system, press the SAVE key. This will store the display in MEM-X.

h. REVIEW THE DATA (MEM-X)

Press the MEM-X key and wait a couple of seconds. The display will change to inverse video and will show the display that you stored a moment ago. This is a static display of data recalled from Quadrex memory. Press the MEM-X key again the display will change back to the standard dynamic display.

9. Using the Bar-Subtract Mode

Next, press the MENU and "6" keys to enter the BAR-SUBTRACT mode (refer to Figure 2.11).

Figure 2.11 Bar-Subtract Display

BAR-SUBTRACT shows the differences between the current data being obtained by the instrument and the data which were previously saved. This display is useful for observing changes in the mass spectrum during the course of a process and for subtracting system background peaks when adding samples to a vacuum environment. BAR-SUBTRACT uses the parameters which were in effect when the BAR-GRAPH/LIB display was saved.

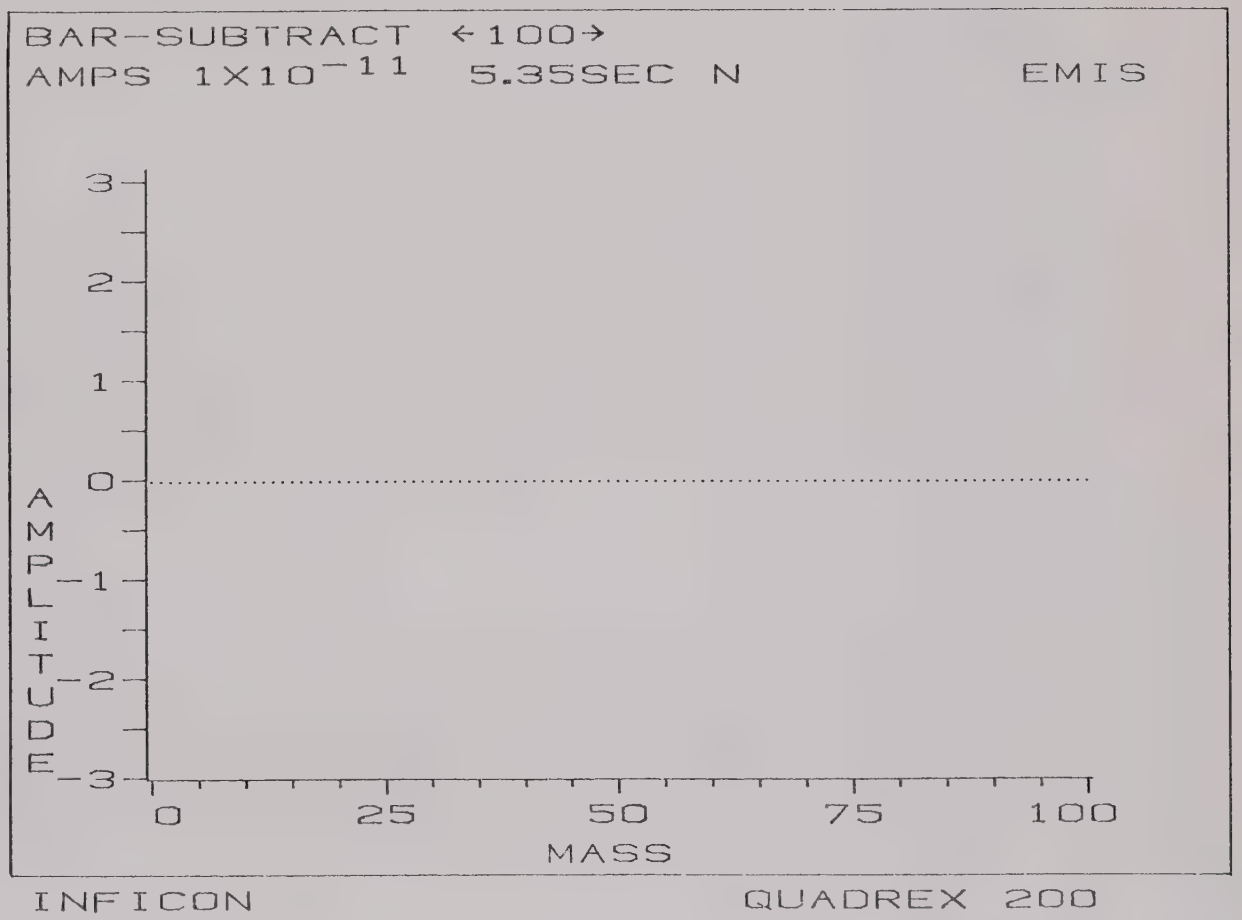


Figure 2.11 Bar Subtract Display

a. OBSERVE THE OPERATION

To observe the operation of the Bar-Subtract mode you must have saved a display in the Bar-Graph/Library mode. You should see a decrease in the water peaks. This decrease is indicated by bars extending down from the 0 AMPLITUDE line. Figure 2.12 shows a decrease in MASS 18.

Figure 2.12 Bar-Substra/Water Peak Display

b. RESET THE SCAN

Notice the small marker which is moving along the horizontal MASS scale line. It starts at the left and scans to the right. This is the scanning function of the display.

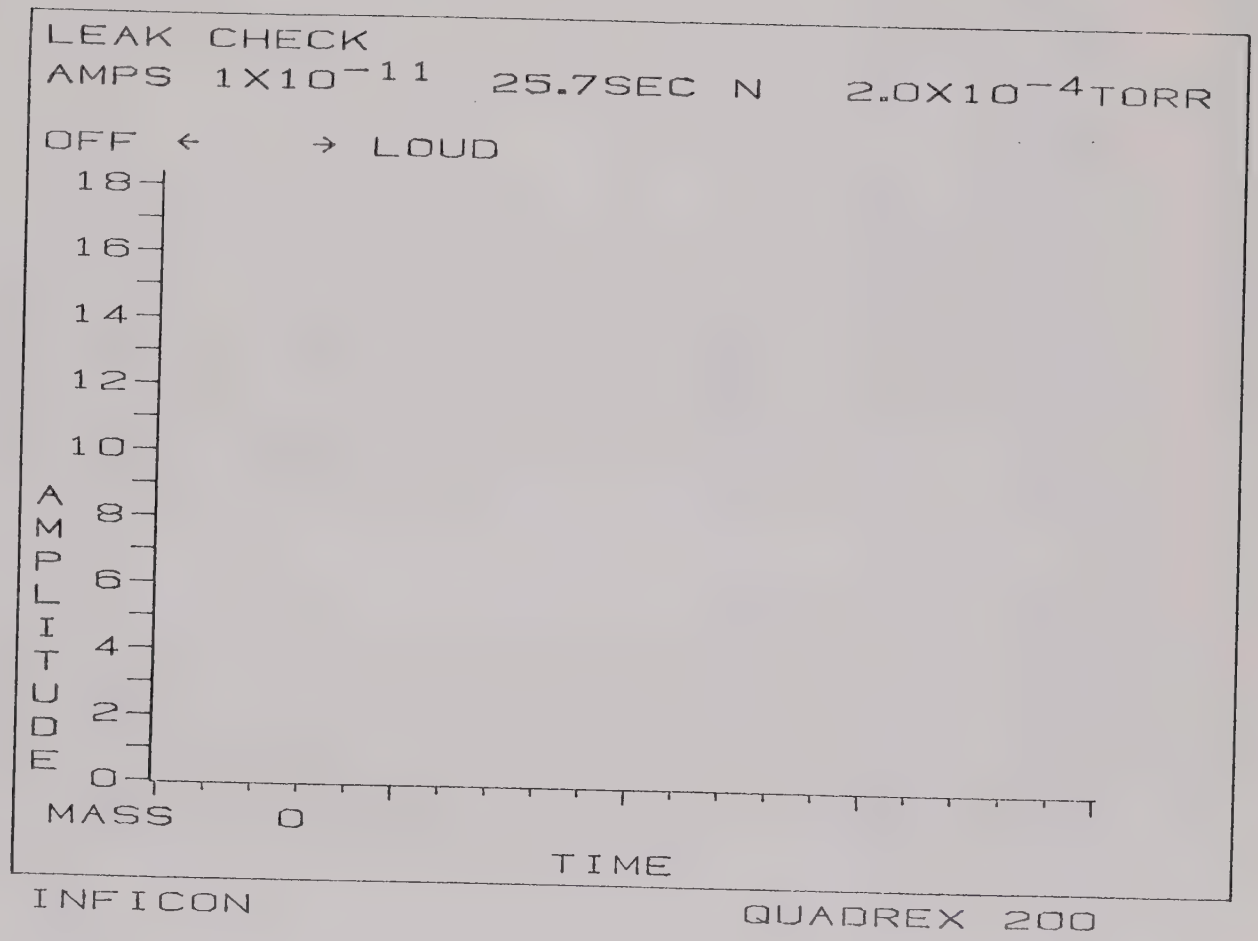


Figure 2.9 Leak Check Display

Press the RESET key and notice that the marker stops and moves back to the left side of the scale and restarts. Changing the scan speed also causes the scan to RESET.

10. Using the User Library

Next, press the MENU and "7" keys to enter the USER LIBRARY display mode (refer to Figure 2.13).

Figure 2.13 User Library

USER LIBRARY mode is not an operational mode. You can enter a set of parameters into the library, and have them available for future use. THis display enables you to store up to six MASS selections, each with an associated relative amplitude value (0 - 100), in each of six USER tables.

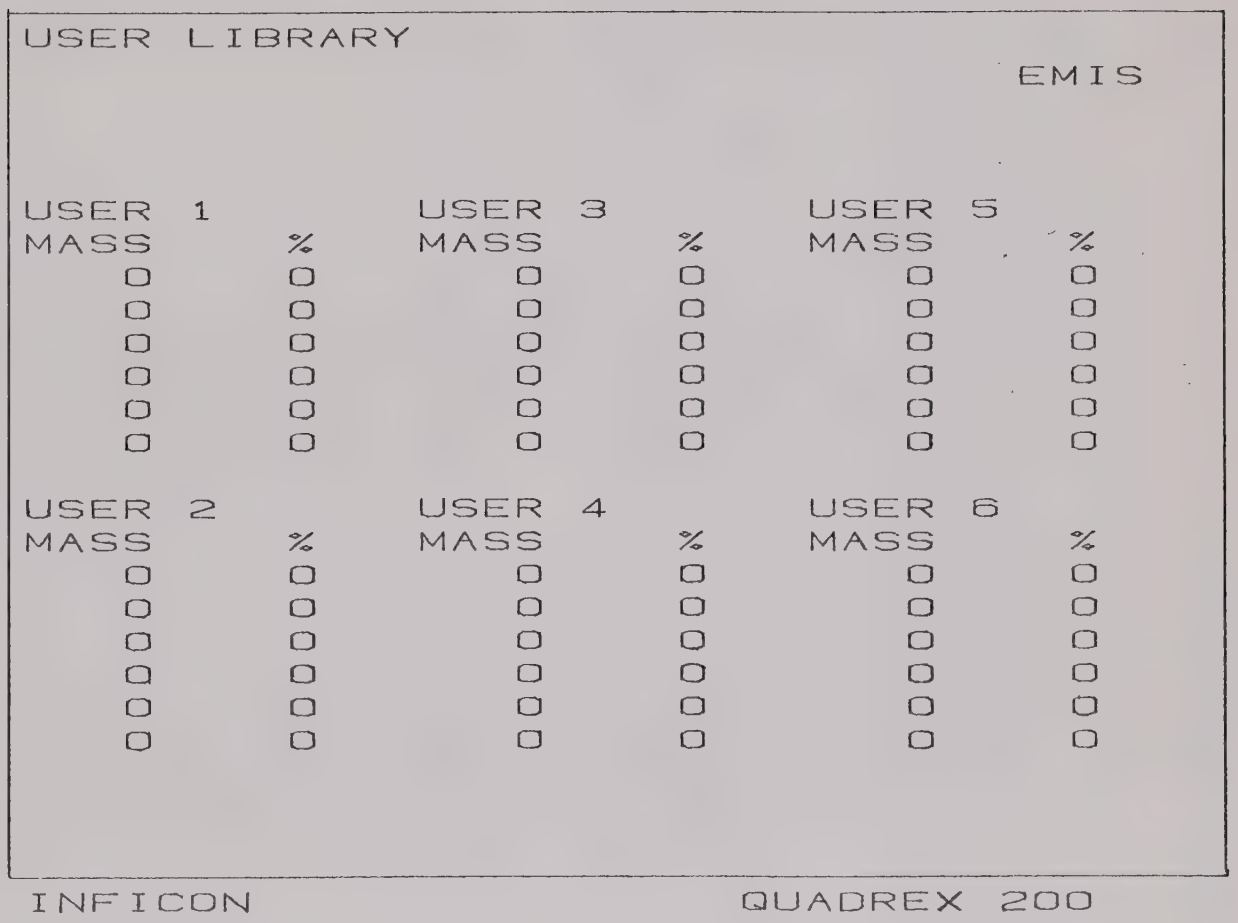


Figure 2.13 User Library

a. SELECT MASS NUMBERS

To enter mass numbers, press any CURSOR key to position the cursor around the first MASS selection in the USER 1 table. Enter any whole number from 1 through 200 and press the "E" key. The cursor will automatically move to the next MASS selection. The CURSOR keys may be used to move the cursor to a different USER table for editing.

b. SELECT AN AMPLITUDE VALUE

Following the last entry in the USER 1 MASS column, the cursor will move to the top of the % column in the USER 1 table. A valid entry in this position is any whole number from 1 through 100 (%). Normally, the largest peak is assigned an amplitude value of 100 and the others are proportioned. The cursor will function as in the MASS column. The CURSOR keys may be used to move the cursor to different USER table for editing.

11. Using the Spectra Library

Next, press the MENU and "8" keys to enter the SPECTRA LIBRARY display mode (refer to Figure 2.14).

Figure 2.14 Spectra Library Display

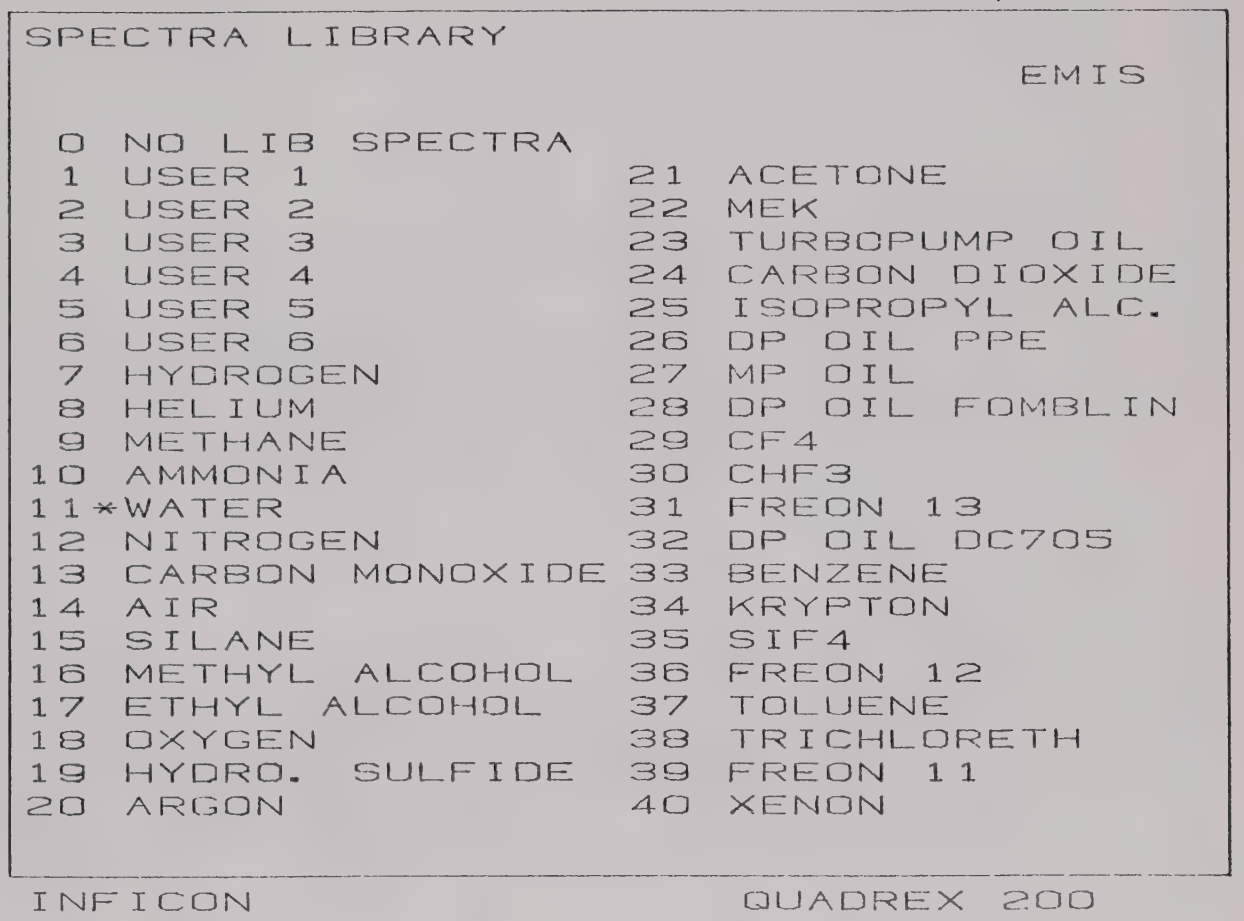


Figure 2.14 Spectra Library Display

a. SELECT A MASS

The SPECTRA LIBRARY display mode shows a list of permanently stored spectra which can be used as references when using the BAR-GRAPH/LIB display mode. You can mark your selection while in this mode by positioning the "*" asterisk beside your selection. To do this press the "E" key to move the asterisk down, and the "C" upwards, through the table. When you enter the BAR-GRAPH/LIB display mode the marked selection will appear in the LIB# position.

Press the "E" and move the asterisk down to the number 10 position AMMONIA. Now, press the MENU and "2" keys. The BAR-GRAPH/LIB display mode will appear with "10 AMMONIA" in the LIB# position along with the static spectrum display for AMMONIA.

This completes the New User's Guide

OPERATIONAL GUIDE

This guide is intended as a quick reference for the experienced user.

CAUTION: **If you are unfamiliar with the basic instrument operation do not attempt to use this guide for operation since many operational steps are not included. Use of this guide by an inexperienced user may result in damage to the sensor.**

Startup

Normal Power-Up	Press POWER switch - menu is displayed, previous memory is saved.
Reset Power-Up	Press and hold Reset button, press POWER switch in until menu appears, memory is cleared.
Emission	Turns sensor on. Push button to turn on or off - has 4 second turn on delay.
Electron Multiplier	(if present) - Automatically turns on with emission - push button to turn on or off.

Functions

Degas	To clean ion source. Press button to turn on or off. Also turns off automatically in two minutes.
Relays	(if present) - Warning indicates relays are inactive, press button to turn on or off.
Save	Press to save current display (Analog, Bargraph, Table, Leak Check, Partial Pressure only).
Mem-x (Normal)	Press button to call up previously saved display (shown in reverse video).
Mem-x (Reset)	Press the RESET button while the recalled display is on screen to make recalled display active. See Mem-X 2-18 definition.
Copy (Normal)	Press button once to create hard copy of all display data with a recorder or plotter.
Copy (Short)	Press button twice to create hard copy of graphical data only.

Displays

Menu	Press button to display menu, then press numbered key to choose menu item to use.
Analog	To view a 10, 20, or 20 AMU portion of the mass spectra. -Gain - change with up/down arrows -Scan speed - change with up/down arrows -EM volts - move cursor to display location using cursor keys, enter new value using numeric keyboard, press E to activate -Center mass - move cursor to display location using cursor keys, enter new value using numeric keyboard, press E to activate. -Scan width - use cursor left/right keys to change scan width -Reset - press to restart scan

Bar Graph/Library	To view a 10, 20, 40, 50, 100, or 200 AMU portion of the mass spectra. -Gain - change with up/down arrows -Scan speed - change with up/down arrows -EM volts - move cursor to display location using cursor keys, enter new value using numeric keyboard, press E to activate -Library Number - move cursor to display location using cursor keys, enter new value using numeric keyboard, press E to activate -Center mass - move cursor to display location using cursor keys, enter new value using numeric keyboard, press E to activate -Scan width - use cursor left/right keys to change scan width -Library Step - use C and E keys to step backward or forward through the library -Reset - press to reset peak finder and restart scan -Range Reset - when range warning is displayed, press to obtain automatic change of scan
Table	Independent measurement on 1 to 6 components in the spectrum. -Scan Speed - change with up/down arrows -EM volts - move cursor to display location using cursor keys, enter new value using numeric keyboard, press E to activate For all functions below - move cursor to display location using cursor keys, enter new value using numeric keyboard, press E to activate -Mass -Gain -Calibration Factor -HLIM -LLIM

Leak Check	View the amplitude of a single peak as a function of time. -Gain - change with up/down arrows -Scan Speed - change with up/down arrows -EM volts - move cursor to display location using cursor keys, enter new value using numeric keyboard, press E to activate -Mass number - move cursor to display location using cursor keys, enter new value using numeric keyboard, press E to activate
Partial Pressure	Monitor partial pressure of 1 to 6 masses in the spectrum. -Scan Speed - change with up/down arrows For all functions below - move cursor to display location using cursor keys, enter new value using numeric keyboard, press E to activate -Unit - enter 1, 2, or 3 -T/MA - enter sensitivity factor -Material - enter mass number -Factor - enter material factor
Bar Subtract	Compare stored Bar-Graph with one presently being measured. Not programmable
User Library	Create custom library spectra for use in Bar-Graph/Library mode. For all functions below - move cursor to display location using cursor keys, enter new value using numeric keyboard, press E to activate -Mass -Value
Spectra Library	Reference for selection of spectra for use in the Bar-Graph/Library mode. -Move Asterisk - use C and E keys to step backward or forward through the library

This ends the Operational Guide.

QUADREX 200 FUNCTIONS

This section includes information on operating characteristics of the instrument. All users should become familiar with information on Warning Messages, Control Keys, Startup Procedure, and the 9 Instrument Displays.

Instrument Operation

WARNING MESSAGES

The following list includes all possible display messages that you may encounter during instrument operation.

Message	Definition
EMIS	The emission is off and the sensor head is not operating.
RELAY	The (optional) set point relays are inactive.
ENTRY ERROR	You have attempted to enter an incorrect or invalid operating parameter. Press the "C" (clear) button to erase the invalid entry and clean this entry message.
PROGRAM LOSS	Previous operating conditions stored in the instrument have been erased and default conditions from an internal table have been inserted into the operating memory.
POWER LOSS	Power to the instrument has been interrupted. The instrument has shut down and restarted. Operation may or may not be impaired depending upon the cause of the fault.
AC DISTURBANCE	There has been a momentary disturbance in the power line which has affected operation of the instrument.
RF FAILURE	The RF generator which operates the ion separating section of the sensor head has failed and spectra cannot be produced.

PRESSURE FAIL	The instrument has shut down because the vacuum level is insufficient.
CABLE ERROR	An attempt has been made to operate the instrument without having the Mass Filter Control Cable Installed.
ANODE HIGH or ANODE LOW	There is a fault in the sensor ion source which has prevented the anode voltage from falling in the normal range.
CATHODE HIGH or CATHODE LOW	There is a fault in the sensor ion source which has prevented the cathode voltage from falling in the normal range.
EMISSION FAIL	There is a fault in the sensor head or elsewhere in the circuit that has caused the emission regulator to shut down.

CONTROL KEYS

The functions listed below are selectable via front panel keys (refer to Figure 2.1 for key location).

MENU

The Menu function enables you to view the list of possible operations and select one using the associated number. The operation functions are listed below numbered in key order:

Key	Function	Definition
1	ANALOG	Examine a part of the spectrum in detail.
2	BAR-GRAPH/LIBRARY	View all or part of spectrum.
3	TABLE	Monitor 1 to 6 components of the spectrum.
4	LEAK CHECK	View the magnitude of one component of the spectrum as a function of time.
5	PARTIAL PRESSURE	Read partial pressures.
6	BAR-SUBTRACT	View the difference between the current spectrum and the one previously stored.
7	USER LIBRARY	A storage table for six user entered spectra
8	SPECTRA LIBRARY	Contains six sets of user programmable spectra and thirty three preprogrammed spectra.
9	TEST MODE	Diagnostic mode for testing software functions with the emission off.

You can call up the MENU display whenever the instrument is operating (except when MEM-X is in effect) by pressing the MENU key. With the MENU display on the screen, you can enter any of the available modes of operation by pressing the corresponding numerical key.

SAVE

The SAVE key permits you to store in the Quadrex 200 memory the contents of the current display as it appears on the screen. You can store one display for each of the Analog, Bar-graph/Library, Leak Check, and Partial Pressure display modes. Stored displays can be recalled later for viewing. Also, the saved BAR-GRAPH/LIBRARY display is used in the BAR-SUBTRACT mode to compare spectral differences. Since only one display (per display mode) can be stored, saving a new display automatically erases any display previously stored for that mode.

MEM-X

The MEM-X key saves the current display and recalls the stored display from the memory for viewing. The data are displayed in reverse video to indicate that they are stored data, and not real time measurements. Pressing MEM-X a second time returns you to the active display. You can configure your Quadrex 200 so that you can use the stored data as active operating commands. (See Section 3, Configuring the Quadrex 200).

COPY

If you have an XY Plotter connected to your Quadrex 200, you can obtain a hard copy of the current display by pressing the COPY button. The data (for copy) is automatically saved in memory until the copy function is complete, allowing you to continue operation while the copy operation is being performed.

NOTE: The standard XY plotter output represents the pictorial part of the screen only.

The optional digital XY plotter allows you two options:

Full plot - displayed information along with the pictorial section of the screen - push the COPY button once for this copy.

Short plot - pictorial section of the screen only - push the COPY button twice within three seconds for this copy.

RESET

The reset key performs several functions, depending on present Quadrex 200 operating conditions.

Using RESET, you can erase the internal memory of the Quadrex 200 (during power up) and insert a standardized set of operating conditions. This operation is useful if random electrical noise has resulted in erroneous information in the Quadrex 200 memory causing incorrect operation. To erase the memory, turn the POWER switch off. Press and hold the RESET button, and turn the POWER on. Continue to hold the RESET button until the MENU display appears.

When the Quadrex 200 is operating in one of the normal display modes, the RESET button causes the instrument to interrupt the current data scan and start over. If the display is in a mode in which the Peak Lock circuit is active, the instrument will pause to do a complete update of the peak finder memories before resuming the data scan.

You can configure your Quadrex 200 so that RESET exchanges the current set of operating conditions with those in the Quadrex 200 memory. (See Section 3 for detailed instructions on configuring the Quadrex 200.) To use this feature, select the display mode in which you wish to operate; then press MEM-X and RESET in that order.

When the instrument is operating in the BAR-GRAPH/LIB mode and the RANGE warning is flashing, the RESET function will increment the MASS width and center MASS to an appropriate level.

EMIS

This key turns the emission circuit on and off. When emission is turned on, there is approximately a 4 second delay before operating voltages are applied to the sensor head. When emission is off, operating voltages are removed from the sensor head.

EMULT

On Faraday Cup units, this key is not active. On Electron Multiplier (EM) units this key allows you to turn the electron multiplier voltage on and off.

DEGAS

Applies a high accelerating voltage and emission current to drive adsorbed gasses off the ion sensor source. Degas periods of 1 to 2 minutes are normally sufficient. DEGAS turns itself off automatically after approximately 2 minutes. Data that may appear on the screen during DEGAS are meaningless.

CURSOR (Keys)

There are four CURSOR keys. The main purpose of these keys is to display and move the cursor on the display screen. Additional functions for these keys are described in the detailed descriptions of the display modes.

NUMERICAL Keypad

There are ten numerical keys 0 through 9 which are used for entry of numerical data.

E (Enter)

Enters new numerical data into Quadrex 200 memory and, in BAR-GRAPH/LIB mode, increments the LIB# number if the existing number is greater than 0.

C (Clear)

Clears an incorrect entry from the Quadrex 200 display screen and, in BAR-GRAPH/LIB mode decrements the LIB# number if the existing number is greater than 0.

RELAY

The RELAY key operates only when the Relay Option Board is installed. Use of this key is described in Section 7.

Electron Multiplier

This section refers only to units that are furnished with the EM Sensor HEad. If you have a Faraday Cup Head, you can skip this section. If you are not sure which head you have, the two heads are described in "Installation", Section 1.

The EM head contains an electron multiplier (a high gain preamplifier) which permits you to see smaller signals. The electron multiplier is contained entirely within the sensor head. To use the electron multiplier, you must have a Sensor Control Unit containing the power supply to operate the EM Sensor Head.

NOTE: You can operate a Faraday Cup Head with a Sensor Control Unit containing an electron multiplier power supply provided your instrument has been tuned to operate properly with a Faraday Cup Head and the configuration switch (See Section 3) has been set to the Faraday Cup position.

When you are operating with an electron multiplier, the operating voltage applied to the multiplier appears in the upper left corner of the display screen. The gain of the multiplier, and thus the sensitivity of the instrument, depends strongly on the operating voltage.

The voltage range available is 1.0 to 3.0 kilovolts, selectable in 10 volt steps. Normally, you should choose a voltage between 1.5 and 2.0 kilovolts.

To set the multiplier voltage, the unit must be running in the active display mode that you wish to use. (Exception - in the Bar-Subtract mode, the multiplier voltage is that which was in effect at the time the reference was stored). First, using the CURSOR up and down keys, move the cursor to the EMUL position in the upper left corner of the display. Enter a 3 digit number in the 100 through 300 range. If the desired number is now shown on the display, press the E key to enter it to memory.

If you are using more than one display mode, you must set the desired multiplier voltage for each mode.

Adjusting the operating voltage for the electron multiplier to change its gain and adjusting the electronic gain of the instrument (as described below) enables you to achieve instrument sensitivity resulting in sueful spectra. Generally, you may use either method to get satisfactory results with a multiplier voltage in the range 1.5 to 2.0 kv. If the signals are too large to display when using the minimum electronic gain, reduce the multiplier voltage as necessary.

With the Quadrex 200, the electron multiplier sensor has a built-in Faraday cup, by setting the EM voltage to zero the Faraday cup portion of the sensor is automatically activated.

CAUTION: Excessive Electron Multiplier output currents cause temporary saturation resulting in loss of multiplier sensitivity.

When using the Electron Multiplier in the:

Bar-Graph/Library Mode	Make sure peaks in the spectrum do not exceed $6x10^{-7}$ amps in height. Reduce the Electron Multiplier voltage for Bar-Graph mode as necessary to meet this requirement.
Table Mode	Make sure values do not exceed $25.4x10^{-8}$ amps at a CAL factor of 1.0. Reduce the Electron Multiplier voltage for the Table mode as necessary to meet this requirement.
Partial Pressure Mode	Do not exceed the Electron Multiplier voltage used in the Bar-Graph/Library mode above.
All Other Display Modes	Do not use an Electron Multiplier voltage which results in outputs greater than $6x10^{-7}$ amp.

Startup Procedure

We will assume that your instrument has been properly installed and connected as described in Section 1. You may want to review those sections again, particularly the one on Electrical Connections, to make sure everything is ready for operation.

CAUTION: In addition to being properly installed, the sensor must be in a vacuum of 10^{-4} torr or better (10^{-5} torr or better for EM head). If the vacuum has not reached 10^{-4} torr, the unit will turn off the operating voltages to the sensor to prevent damage to the head.

Set the instrument POWER switch to ON. Once the Quadrex 200 initializes, the MENU should appear (about 15 seconds). If you don't get the MENU display (Figure 2.15) refer to the Troubleshooting section of this manual.

Figure 2.15 Menu Display

At this time, you should see the words "EMIS" and "POWER LOSS" flashing.

[If you have the Relay option, the word "RELAY" will also be flashing. If you have erased the memory, the words "PROGRAM LOSS" will be flashing instead of "POWER LOSS".] The "EMIS" warning indicates that the emission circuit is off and power has not been applied to the Sensor Head.

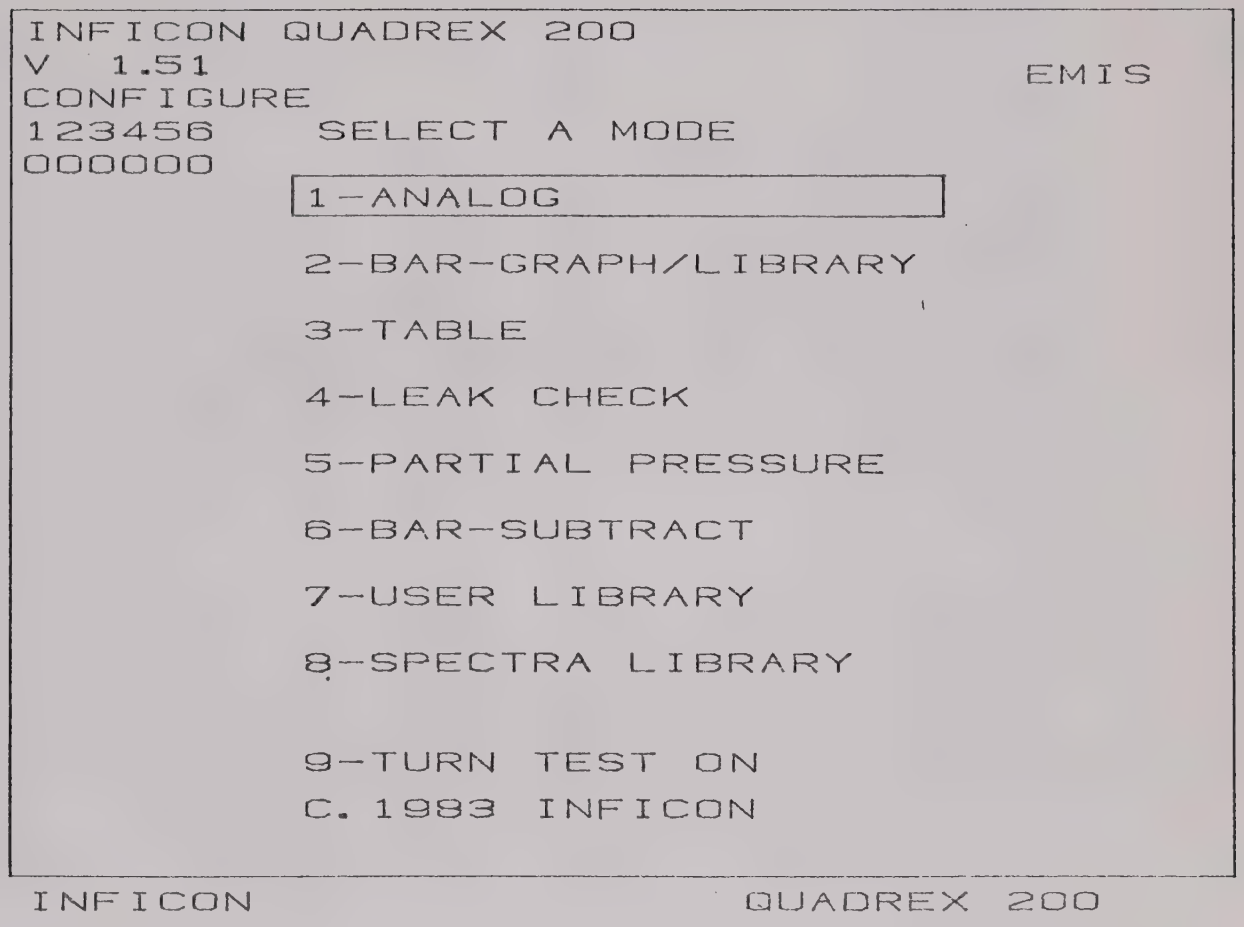


Figure 2.15 Menu Display

Press the EMIS switch to turn on the sensor head. The EMIS warning message should disappear and remain off. The pressure reading will appear in the upper right hand corner of the screen after 4 seconds. If the EMIS warning comes on again, there is a fault in the system or insufficient vacuum. The instrument will display an additional message indicating the type of fault. Correct the problem before proceeding. Refer to the Troubleshooting section if necessary.

Select the display mode that you want to use by pressing the numerical key shown in MENU.

The Quadrex 200 is now in operation.

Instrument Displays

The nine display modes are described below in detail. The first six of these displays are dynamic, two are static, and the ninth mode is a software diagnostic.

NOTE: To use the Electron Multiplier described in the next paragraph your Quadrex 200 must be configured for use with an EM sensor head. See Configuring the Quadrex 200.

In the dynamic displays you must select the Electron Multiplier voltage (if you are using an Electron Multiplier) for each display. One exception to this is the Bar-Subtract mode which uses the voltage setting from the stored Bar-Graph/Library display. To set the Electron Multiplier voltage move the cursor to the EMULT position on the display and enter a voltage level from 1.00kv to 3.00kv in 10 volt increments. Press the E key. Refer to the CAUTION in the Electron Multiplier description above.

Display 1 ANALOG (Examining details of spectrum peaks)

The Analog display permits you to examine a 10, 20, or 40 AMU portion of the mass spectrum in greater detail. You may wish to observe the actual shape of the mass peaks that are developed by the sensor during troubleshooting, maintenance or when you want to be sure that small peaks are not being distorted by the presence of large peaks at nearby masses.

A typical Analog display is shown in Figure 2.13.

In this operating mode you can select the mass width and center mass, the instrument sensitivity (AMPS), the scanning speed, and the electron multiplier voltage (if you have an electron multiplier).

SELECT THE MASS WIDTH

The Analog display mode is capable of displaying the data in the 10, 20, or 40 AMU Mass Width range, however, on initial power up the instrument sets the mass width to 20 AMU. A lower mass width allows you to view the spectrum in greater detail, while greater mass width allows you to view a greater portion of the spectrum. To change the mass width, position the cursor at the mass width position (top of display screen) and enter the appropriate number.

SELECT THE CENTER MASS

Once you have determined the mass width to be used you can select a center mass which is at least one half the value of the mass width at the end of the range; and no greater than one half of the mass width at the high end of the range. For example, if you chose a mass width of 10 AMU, the center mass must be no less than 5 AMU and no greater than 195 AMU. Likewise, if you choose a mass width of 40 AMU, the center mass must be no less than 20 AMU and no greater than 180 AMU. In default conditions, the mass width is automatically set to 20 AMU the center mass is set to 10 AMU. To change this value position the cursor at the center mass position (bottom of display screen) and enter the appropriate new number. If the new number is within the acceptable range of the mass width the instrument will begin scanning at the beginning of the new mass range. If the Quadrex 200 does not accept the new center mass number an ENTRY ERROR warning message will appear on the display. If this occurs you should clear it with the "C" key and enter a valid number for the mass width in use.

ADJUST THE GAIN

The GAIN keys are used to adjust the sensitivity of the instrument so that the height of the peaks of interest falls within the visible part of the display area. (On EM units, be sure the desired EMULT voltage has been set; read "Electron Multiplier", pages 2-32 - 2-34). To increase the peak height, press the GAIN key marked ↑, to decrease the height push the GAIN key marked ↓.

SELECT THE SCANNING SPEED

Increase or decrease the scanning speed by using the up or down arrows marked SPEED. Available speeds are VERY SLOW, SLOW, NORMAL, FAST, and VERY FAST and are indicated at the top center of the display. In all cases, as you increase the instrument GAIN the scanning speed will slow down automatically. Decreasing GAIN will cause an automatic increase in scanning speed. These changes in the scanning speed are necessary to give the instrument time to adequately filter noise from the output signal of the sensor. The VERY FAST scan option gives you more speed and less filtering than normal. The VERY SLOW scan option gives you more filtering if you are willing to operate with a slower scan speed.

RESET THE DISPLAY SCAN

Scanning is automatic in the Analog display mode. You will notice that the scan restarts each time you change the gain or scan speed. You can also start a new scan by pressing the reset button.

You can SAVE and/or COPY a display in the Analog Display mode.

DISPLAY 2 BAR-GRAPH/LIBRARY

The BAR-GRAPH/LIB display mode is the main mode of operation in the Quadrex 200 and may be used in two ways.

First, you may view all or part of the spectrum, with a full screen display. Each vertical bar represents the amplitude of one mass peak. In order to view the bar graph properly, the height of these bars should not go above the top of the vertical scale. A typical Bar-Graph display is shown in Figure 2.16.

Figure 2.16 Bar-Graph Display

Second, by selecting one of forty Library selections you may view split screen display, as a reference for comparison with the dynamic Bar-Graph directly below. If a change is made to the dynamic display Mass Width the static display is automatically adjusted to compensate. A typical Bar-Graph/Library display is shown in Figure 2.4.

SELECT THE MASS WIDTH

The BAR-GRAPH/LIB mode is capable of displaying the data in the 20, 40, 50, 100, or 200 AMU Mass Width range, however, on initial power up the instrument sets the Mass Width to 50 AMU. To change the Mass Width, position the cursor at the Mass Width position (top of display screen) and enter the appropriate number.

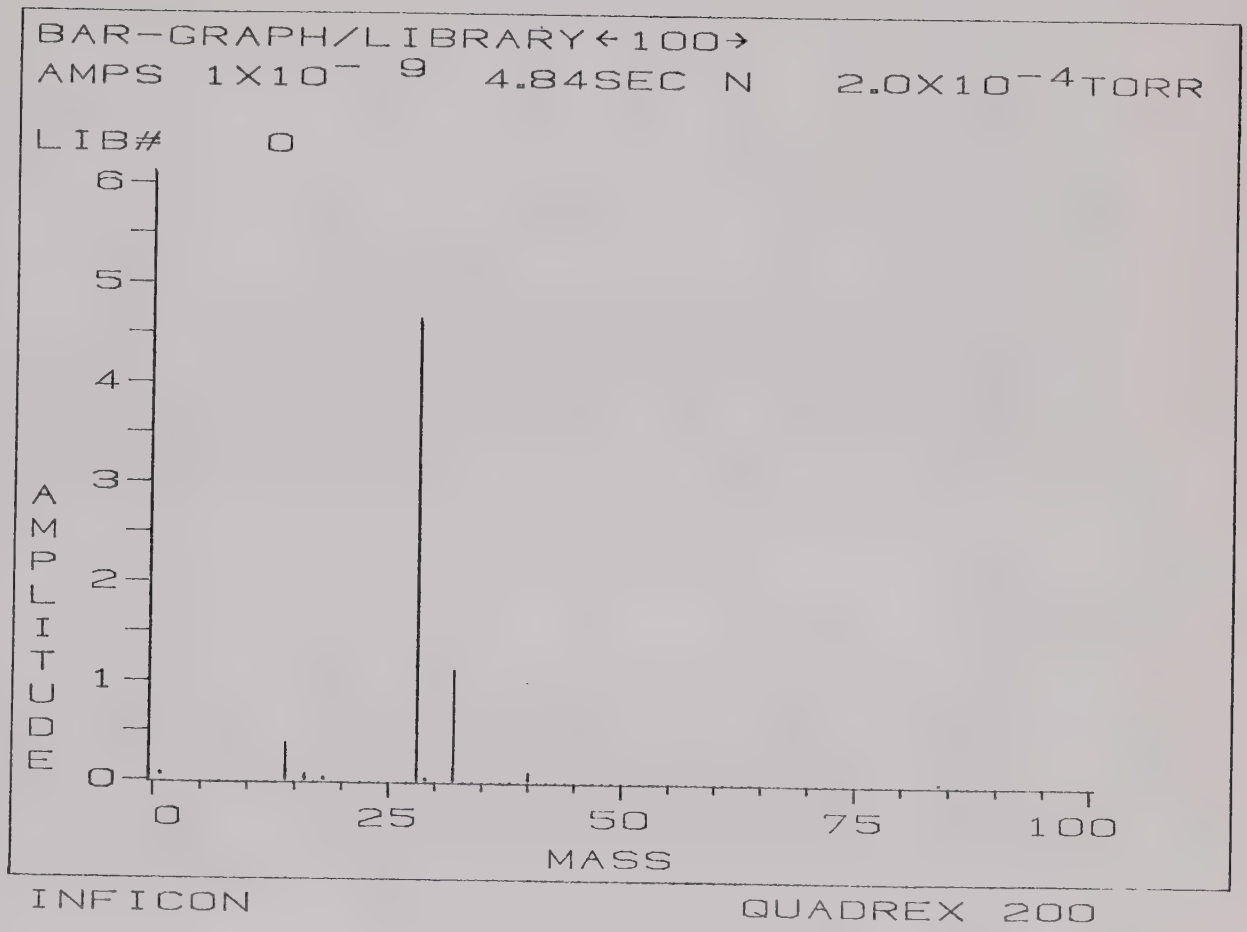


Figure 2.16 Bar Graph Display

SELECT THE CENTER MASS

A new center mass may be selected in the 20, 40, 50, and 100 AMU ranges provided the new mass value is greater than or equal to 1/2 of the range value. That is, a new center mass of 25 or greater may be selected in the 50 AMU range; a new center mass of 24 will result in a flashing ENTRY ERROR warning.

To change the center mass use the cursor up/down keys and the keyboard at the right end of the front panel. The cursor appears on the screen as a rectangular outline and is used to identify the number you want to change on the display. The down arrow on the cursor control moves the cursor to the center mass number which is displayed at the bottom of the screen. Enter the new mass number by pressing the numerical keys on the keyboard. When you do this the cursor will flash, indicating that the number on the screen is not the number stored in memory. If the number on the screen is not the number you wish to enter, you can clear it by pressing the key marked "C" (Clear) on the keyboard. When you have the correct number on the screen, enter it into the instruments operating memory by pressing the "E" (Enter) key on the keyboard. If the number you have entered is a valid number, the cursor will disappear and the scale will change, indicating the new operating mass range of the instrument. The instrument will also begin scanning at the beginning of the new mass range. If the Quadrex 200 does not accept the new center mass number that you have attempted to enter, you should clear it with the "C" key and enter a valid number.

ADJUST THE GAIN

The GAIN keys are used to adjust the sensitivity of the instrument so that the height of the peaks of interest falls within the visible part of the display area. (On EM units, be sure the desired EMULT voltage has been set; read "Electron Multiplier", pages 2-32 - 2-34). To increase the peak height, press the GAIN key marked ↑, to decrease the height push the gain key marked ↓.

To obtain the numerical value of the signal (in amps), multiply the vertical scale reading for a given bar by the multiplier shown in the upper left corner of the screen.

SELECT THE SCANNING SPEED

Increase or decrease the scanning speed by using the up or down arrows marked SPEED. Available speeds are VERY SLOW, SLOW, NORMAL, FAST, and VERY FAST and are indicated at the top center of the display. In all cases, as you increase the instrument GAIN the scanning speed will slow down automatically. Decreasing GAIN will cause an

automatic increase in scanning speed. These changes in the scanning speed are necessary to give the instrument time to adequately filter noise from the output signal of the sensor. The VERY FAST scan option gives you more speed and less filtering than normal. The VERY SLOW scan option gives you more filtering if you are willing to operate with a slower scan speed.

USING THE LIBRARY

To select the Library display press any cursor key and position the cursor around the number presently in the Library # position, enter a new number and press the "E" key. If the number in the Library # position is 1 through 40, you can change it simply by pressing the "E" key to increase the number or the "C" key to decrease the number. If the new mass selection falls outside of the mass range selected, the RANGE warning message will flash on the display. Press the cursor right key to increase the range until the warning message disappears or press RESET for an automatic selection of Center Mass and Mass Width. [For a more detailed description of the Library display see the Spectra Library Display description.]

To return to the normal Bar-Graph display select 0 for the LIB#.

RESET THE DISPLAY SCAN

Scanning is automatic in the Bar-Graph/Library display mode. You will notice that the scan restarts each time you change the gain or scan speed. You can also cause the instrument to start a new scan by pressing the RESET button.

You can SAVE and/or COPY a display in the Bar-Graph/Library mode.

DISPLAY 3 TABLE

This section describes the Table Display. A typical Table Display is shown in Figure 2.7. The Table display differs from other displays described above in that one to six components can be selected from the spectrum. Each component can be measured using independent parameters for AMPS (gain), CAL (calibration), HLIM (high limit), and LLIM (low limit).

The upper part of the display is a table of operating commands that the Quadrex 200 uses in making measurements for this mode of operation. Since the Table display may be used for process control or interlocking, you should not change the operating table values if the instrument is being used in this manner. The output of the instrument for each selected component is displayed numerically in the row marked "VALUE"

and graphically in the lower part of the display. In the graphical display the height of each bar represents the magnitude of the measured signal and the pair of dashes indicates the set point or target value for this signal.

PROGRAMMING THE TABLE DISPLAY PARAMETERS

If the Table display has not previously been set up, you must program the parameters as follows:

Press any cursor key to get the cursor to appear on the Table display. Using the cursor up, down, left, and right keys position the outline around the parameter to be entered. Using the numerical keys, enter the numbers in the normal left to right sequence. The numbers will be displayed as you write them and the cursor will flash indicating that the numbers on the display are not those currently in the operating memory. If the number in the display is not the one you wish to enter press the "C" (CLEAR) key and re-enter the number. When you have the desired number displayed on the screen press the "E" (ENTER) key to place number into operating memory. If the Quadrex 200 accepts the number you have entered the cursor will stop flashing and move to the next programmable parameter. If you have entered an invalid number (the ENTRY ERROR warning flashing) press the "C" (CLEAR) key and enter a valid number.

You must enter the mass of the component you wish to measure in a given channel. Valid mass numbers are whole numbers in the 1 to 200 range. If you wish to skip a channel, enter the number "0" for this channel.

The electronic gain that you wish the instrument to use in measuring the output of the specified mass must be programmed separately for each active channel. The number that you enter is the exponent. That is, an entry of 9 means that you have selected the 10^{-9} amp range. Permissible values are 8 through 13 for Faraday Cup units and 8 through 11 for Electron Multiplier units.

You can also insert a multiplication factor for calibration corrections. Normally, a value of 1.0 should appear at this point. However, you can enter a number from 0.1 to 9.9; the Quadrex 200 will multiply the sensor output by this factor and display the product. When you enter calibration factors, do not enter a decimal point but do enter both digits of two digit numbers. That is, to enter 1.0, press the keys 1 and 0 in that order.

You can enter a High Limit set point (HLIM) and a Low Limit set point (LLIM) for each channel. Permissible set points are 0.0 through 10.0. The Quadrex 200 does not permit you to enter the decimal point, but you are required to enter all of the digits as described in the paragraph above.

SELECT THE SCANNING SPEED

Increase or decrease the scanning speed by using the up or down arrows marked SPEED. Available speeds are VERY SLOW, SLOW, NORMAL, FAST, and VERY FAST and are indicated at the top center of the display. In all cases, as you increase the instrument GAIN the scanning speed will slow down automatically. Decreasing GAIN will cause an automatic increase in scanning speed. These changes in the scanning speed are necessary to give the instrument time to adequately filter noise from the output signal of the sensor. The VERY FAST scan option gives you more speed and less filtering than normal. The VERY SLOW scan option gives you more filtering if you are willing to operate with a slower scan speed.

You can SAVE and/or COPY a display in the Table display mode.

DISPLAY 4 - LEAK CHECK

The Leak Check display shows the amplitude of the single peak as a function of time on the screen. This form of display is a convenient means of watching for changes or trends in peak amplitude and can be used to detect the appearance or disappearance of trace gas used in leak testing. An audible alarm is programmable for three levels of intensity. The cursor up and down keys are used to increase or decrease the volume of the alarm. An indicator of volume level is located in the upper left quadrant of the Quadrex 200 display. As the volume level is increased from OFF, a dash will appear for each step. Available volume settings are OFF, SOFT, MEDIUM, and LOUD. A typical Leak Check display is shown in Figure 2.9.

ADJUST THE GAIN

You can change the sensitivity of the instrument in Leak Check mode by using the Gain keys marked ↑ and ↓. Press ↑ to increase the sensitivity and ↓ to decrease the sensitivity. [If you have an EM unit, be sure you have set the EMULT voltage at the desired level.]

SELECT THE SCANNING SPEED

Increase or decrease the scanning speed by using the up or down arrows marked SPEED. Available speeds are VERY SLOW, SLOW, NORMAL, FAST, and VERY FAST and are indicated at the top center of the display. In all cases, as you increase the instrument GAIN the scanning speed will slow down automatically. Decreasing GAIN will cause an automatic increase in scanning speed. These changes in the scanning

speed are necessary to give the instrument time to adequately filter noise from the output signal of the sensor. The VERY FAST scan option gives you more speed and less filtering than normal. The VERY SLOW scan option gives you more filtering if you are willing to operate with a slower scan speed.

RESET THE DISPLAY SCAN

Scanning is automatic in the Leak Check mode. You will notice that the scan restarts each time you change the gain. You can also cause the instrument to start a new scan by pressing the RESET button.

You can SAVE and/or COPY a display in the Leak Check display mode.

DISPLAY 5 PARTIAL PRESSURE

This mode of display provides a direct readout of the partial pressures of selected gas species. All other Quadrex displays show the output current of the sensing head. Consequently there are some specific differences to be observed in using this mode of display:

1. Gas species must be known, so that an appropriate material calibration factor will be used.

2. The instrument sensitivity must be known; for EM instruments, the multiplier voltage used must correspond to the programmed instrument sensitivity.

3. Upon entering this mode, automatic gain range and peak lcck may require several cycles of readings before they stabilize.

4. Non-significant small readings of some gas species may occur when large partial pressures of other species are present.

Section 4 on Theory and Interpretation explains the details of this mode starting on page 4-14.

A typical Partial Pressure display is shown in Figure 2.10. In this display, the left hand column identifies six common gas species by name and allows for six more user-entered species to be identified by mass number. [(N2/CO) indicates that this reading is a combination of nitrogen and carbon monoxide partial pressures, which are not distinguished by the Quadrex 200.] The center column shows the material sensitivity factor for this species. The right hand column shows the measured partial pressure in scientific notation.

You can program the units of measurement, the instrument sensitivity factor and each material sensitivity factor. You can also enter six mass numbers of materials that you want the instrument to detect.

SELECT THE UNIT OF MEASUREMENT

The UNIT number enables you to specify a readout in torr (Unit 1), millibars (Unit 2) or pascals (Unit 3). To change the unit number, move the cursor to the UNIT position. Using the numerical keys, enter number 1, 2, or 3. The number will be displayed when you enter it and the cursor will begin to flash indicating that the number on the display is not the one currently in the operating memory. If the number in the cursor is not the one you wish to enter, press the "C" (CLEAR) key and re-enter the number. When you have the desired number on the display screen press the "E" (ENTER) key to place the number into operating memory. If the Quadrex 200 accepts the number you have entered, the cursor will stop flashing and move to the next programmable parameter. If you have entered an invalid number (the ENTRY ERROR warning flashing) press the "C" (CLEAR) key and enter a valid number.

SET THE T/MA

T/MA is an instrument sensitivity factor which affects the measurement of all gas species. A nominal value, 5.0E-0 is preprogrammed in the instrument. You can change this value to account for the characteristics of your particular instrument. If you have an EM, the correct T/MA value will depend strongly on the electron multiplier voltage. To determine the proper factor to enter here, refer to the detailed discussion in Section 4 Theory and Interpretation.

CHANGE THE MATERIAL FACTOR

You can change the material factors in the center column of the table by using the cursor and numerical keypad. To enter a new factor, move the cursor to the factor column and enter the new number as described in the paragraph above. You should not ordinarily change these numbers except in one of the following circumstances:

a. You have determined, by experiment or otherwise, that a different factor gives a more accurate result, or

b. You wish to read "nitrogen equivalent" pressures, and if with an ionization gauge, in which case the factor should be 1.000, or

c. You are programming one of the user-selectable species for which the Quadrex has no pre-established factor.

ENTER ADDITIONAL MATL/MASS SELECTIONS

The last six entries in the table are also user programmable so that you can specify other gas types that are important to your application. To use one of these, enter the mass number of the peak that you want the Quadrex to use in column 1, using the cursor and keypad. You can use any mass number from 1 through 200. If the gas that you were to measure has several peaks in its spectrum, you can use any of these peaks. You should select one which is unique to this gas and for which you know the material sensitivity factor (unless you want to use "nitrogen equivalent"). The discussion on Interpretation of the Mass Spectra in Section 4 will give more specific information on commonly observed gases.

You can SAVE and/or COPY a display in the Partial Pressure mode. You can also select SCAN speeds in this mode. With EM units you can select the EM voltage.

DISPLAY 6 BAR-SUBTRACT

You can view and compare the stored bar graph of a spectrum with the currently measured spectrum by selecting the Bar-Subtract mode. To use this mode, you must have a previously stored bar graph of a spectrum that you wish to compare with the currently measured spectrum. A typical display taken in Bar-Subtract mode is shown in Figure 2.11. The display represents the difference between the heights of the vertical bars in the current spectrum and those in the previously stored spectrum. Bars above the line indicate that the current spectrum amplitudes are greater; bars below the line indicate that the current spectrum amplitudes are less than those previously stored.

PARAMETERS

In the Bar-Subtract mode, there are no programmable operating parameters; in order to determine valid differences, the Quadrex 200 automatically changes the operating parameters to those which were in effect when the stored spectrum was saved.

You can COPY a display in the Bar Subtract display mode, but you can not save it in the internal memory of the Quadrex 200.

DISPLAY 7 USER LIBRARY

The User Library mode enables you to create custom library spectra for use in the Bar-Graph/Library mode. Each of the six User Library tables will accept six user selected mass numbers and associated percentage values. The largest peak is normally assigned a value of 100, other peaks are then assigned values relative to the largest.

SELECT A MASS NUMBER

To enter a Mass number, press the cursor down key to obtain the cursor on the display. It will be located in the User 1 table at the first mass position. Enter up to a three digit number in the 1 through 200 range and press the E key. Once the mass number is entered, the cursor will move down to the next position.

SELECT A % VALUE

To enter a percentage value, press an appropriate CURSOR key (depending on the present position of the cursor) to move the cursor to the percent value you wish to change. Enter up to a three digit number in the 1 through 100 range and press the E key. Once the % value is entered, the cursor will move down to the next percent value position.

USE THE USER LIBRARY

To use the custom spectra that you have entered into the User Library, you must select the Bar-Graph/Library mode. Since this is a Library function, select the number in the User Library that you wish to use and enter it into the LIB# position (refer to the Bar-Graph/Library display description). Once selected, the library portion of the display will contain all of the data for the User Library table chosen.

DISPLAY 8 SPECTRA LIBRARY

The Spectra Library display provides the user with a list of 40 selections to be used in conjunction with the Bar-Graph/Library display. Included in the 40 selections are: the 6 User Library selections, each with user entered values, and 34 standard AMU selections each with factory set values. Selecting 0 will result in NO LIBRARY SPECTRA. Upon entry into the Spectra Library display, an inverse video asterisk will appear beside selection 0 (unless previously changed). The asterisk may be used to mark a particular selection for automatic entry in the Bar-Graph/Library mode. To move the asterisk press the "E" key to move down through the list or the "C" key to move up through the list. Once the asterisk is positioned beside the desired selection, entry into the Bar-Subtract/Library display will automatically result in that selection being displayed in the Library section of the display.

You can COPY a display in the Spectra Library mode but you can not SAVE the display in Quadrex 200 memory.

DISPLAY 9 TEST

The MENU display allows you to operate the Quadrex 200 in the TEST mode as an aid in troubleshooting. When you select the TEST mode operation (Key 9), an artificially derived signal is injected into the amplifier in place of the sensor output. This signal will produce the displays shown in Figures 2.17, 2.18, and 2.19, if the preamplifier and other data handling circuits are functioning correctly. It is important that the gain is set as shown in the example displays. If you are not able to produce the proper test signals, the cause is in the SCU preamplifier card, the Mass Filter Control cable, or the Operators Console Control and Measurement card.

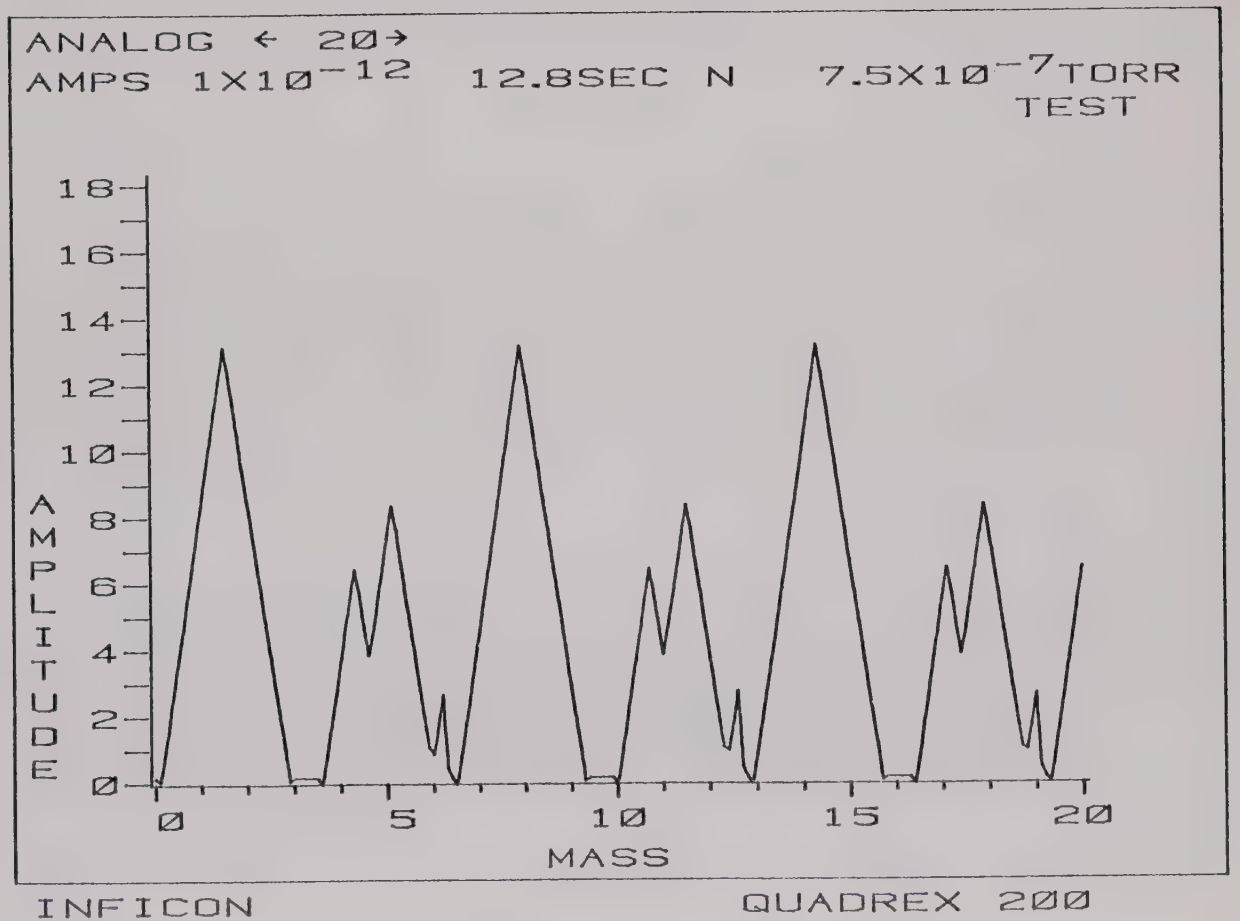


Figure 2.17 Analog in Test

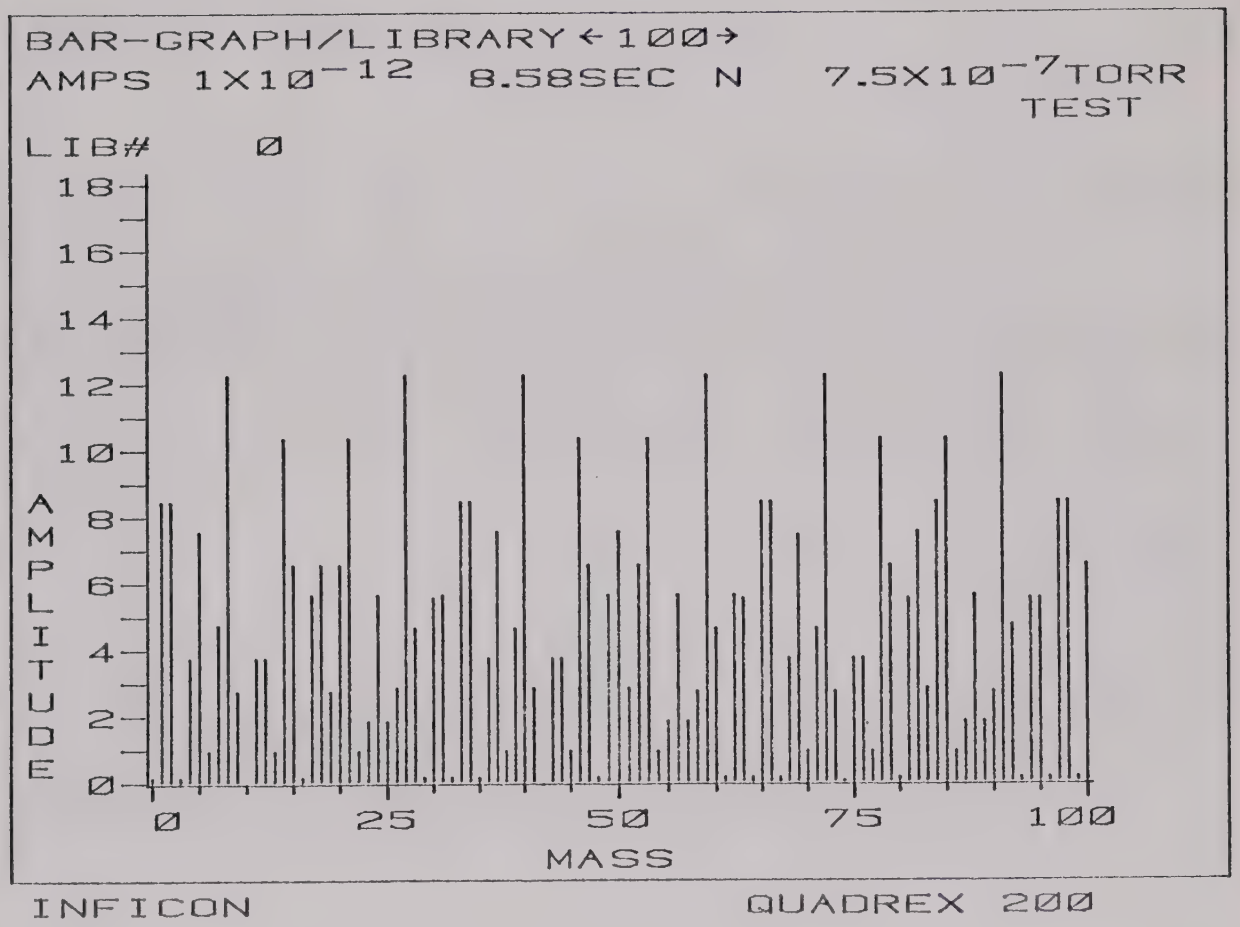


Figure 2.18 Bar Graph Test

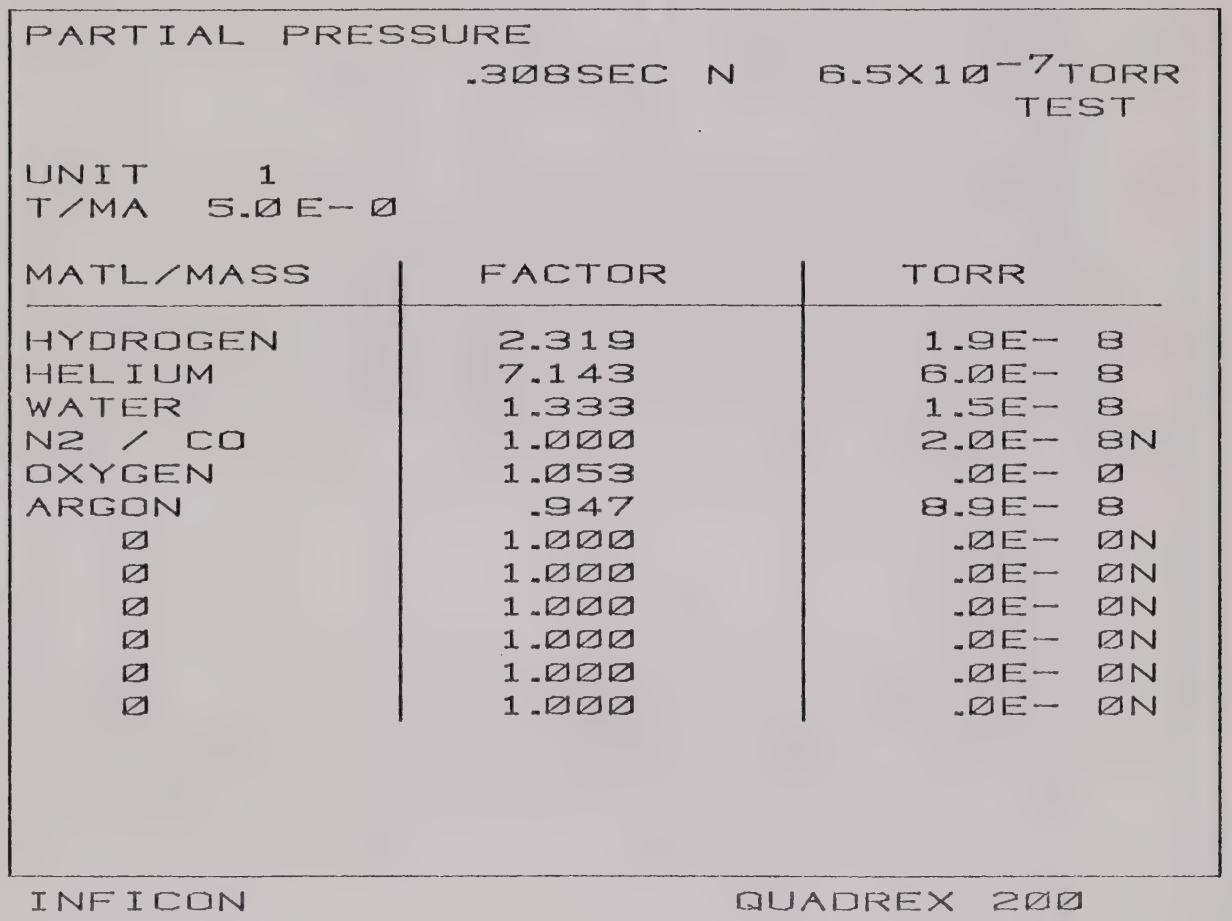


Figure 2.19 Partial Pressure Test

SECTION 3
CONFIGURING AND ADJUSTING THE QUADREX 200

If you are an advanced user and wish to modify the Quadrex 200 for special purposes, this section is for you. Except for changing the CRT line frequency selector from 60 to 50 Hz, don't make any of these changes or adjustments until you are completely familiar with the installation and operation of the Quadrex 200 and have studied these procedures in detail.

You should also read Section 4 - Theory and Interpretation before making the adjustments below.

The first part of this section refers to setting the internal switches to modify the operating modes. Explanations as well as detailed instructions are included.

The latter part of Section 3 describes adjusting the sensor driving circuits to correct for instrument changes which may occur.

Following is a brief outline of the information in this section:

CONFIGURING THE QUADREX 200
- Instructions for Modifying
- Internal Switch Functions

QUADREX 200 ADJUSTMENTS
- Peak Width Adjustments
- Peak Position Adjustments

SECTION 3
CONFIGURING AND ADJUSTING THE QUADREX 200

CONFIGURING THE QUADREX 200

Configure the Quadrex 200 (modify the operating modes) by changing certain switches on the internal CPU board. The instructions for modifying are described below followed by a description of the function of each switch.

WARNING: High voltages are present inside this unit when power is applied. DO NOT open the cover unless the power cord is removed from the rear of the unit.

NEVER OPERATE WITH THE COVER OFF!

Instructions for Modifying

1. Remove the two screws in the upper corners of the rear panel so that the top of the Operator's Console can be removed by sliding it to the rear. Take the top completely off. (See Figure 3.1).

Figure 3.1 Operator's Console Cover

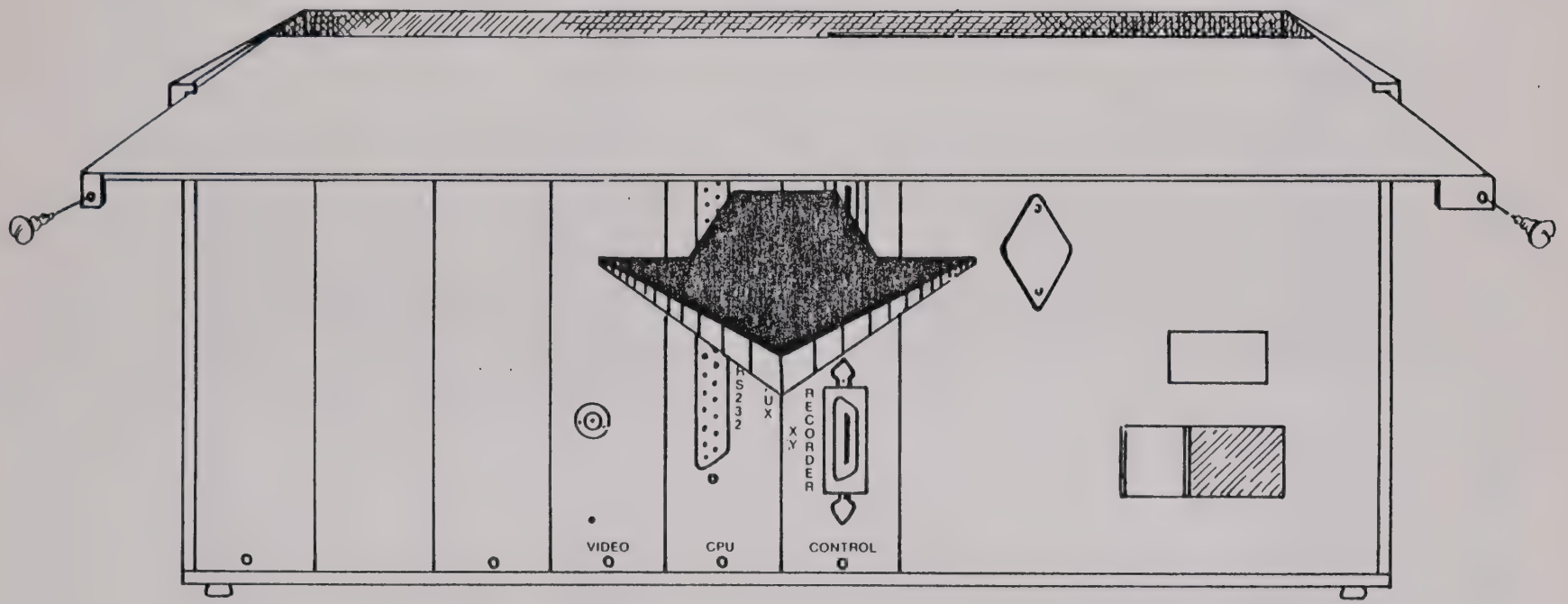


Figure 3.1 Operator's Console Cover

2. Remove the CPU board (No. 017-332) which is the long printed circuit board in the middle of the unit (Figure 3.2). To remove this board, take out the three screws on the rear of the panel holding it in place - then lift the board straight out of its socket.

Figure 3.2 CPU Board

3. To change the settings on the configuration switches, lay the processor board down in front of you with the component side facing you and the connectors at the bottom, as shown in Figure 3.3.

Figure 3.3 Configuration Selector Switch

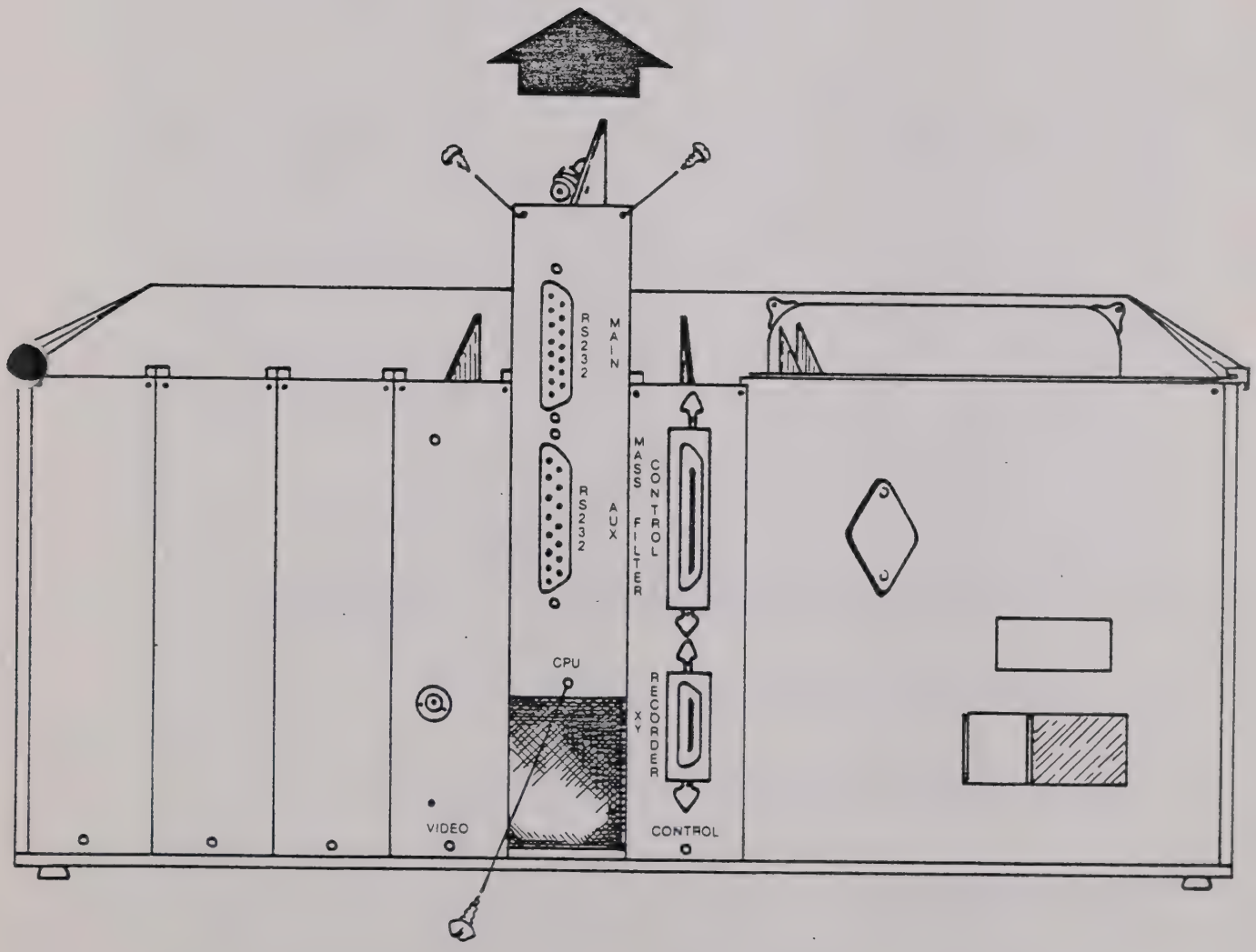


Figure 3.2 CPU Board

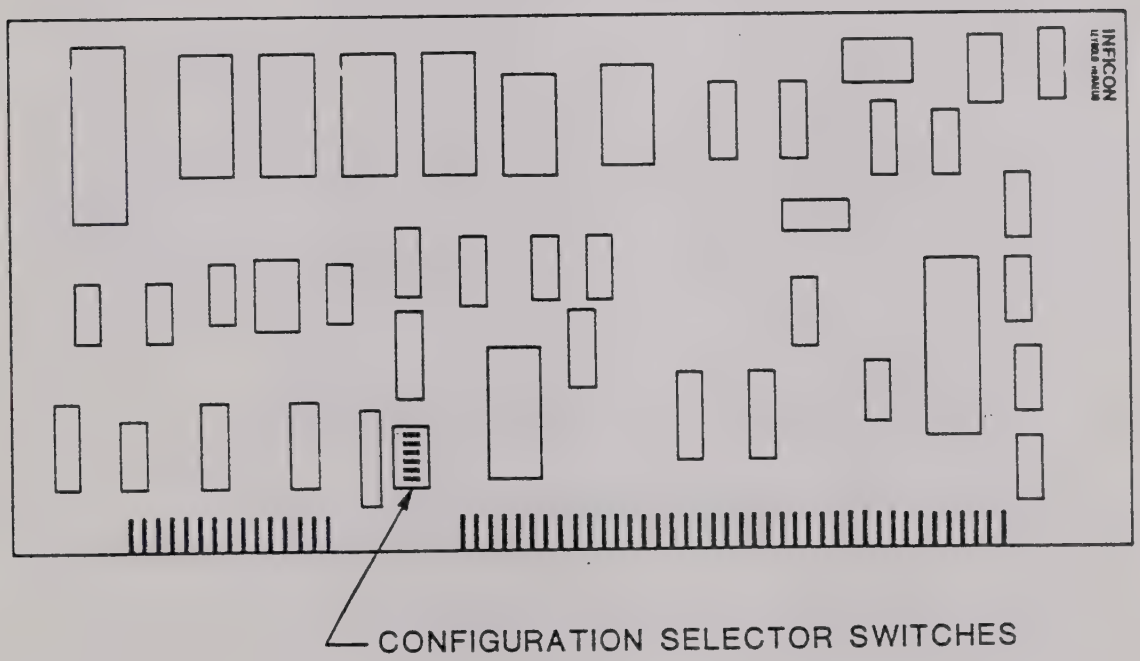


Figure 3.3 Configuration Selector Switch

The configuration switches are in the block marked S2 near the lower edge of the board, approximately 2" to the left of the center. The switches are numbered from the top -- 1, 2, 3, 4, 5, 6.

4. Set the switches to select the desired functions as described below.

5. Replace the CPU board carefully, noting that there are alignment slots to insure the correct mating of the board and sockets. Make sure the board is fully inserted in the sockets. Install the 3 screws in the rear panel and replace the cover.

WARNING: Reinstall the cover before applying power to the unit.

Internal Switch Functions

Your unit may have rocker switches or slide switches, and the switch assembly will be marked OPEN or ON to indicate the direction that the switches will act. For this discussion OPEN = OFF and CLOSED = ON; depress the rocker or slide the sliding bar to the desired position, according to the following table.

SWITCH	DEFINITION
S2-1	CRT Line Frequency Selector Switch. Open = 60 Hz, Closed = 50 Hz.
S2-2	Sensor type Selector Switch. Open = Faraday Cup (FC), Closed = Electron Multiplier (EM).

NOTE: Operation of an Electron Multiplier (EM) system requires that your sensor interface unit include the EM power supply which supplies high voltage to the electron multiplier. You can operate the FC sensing head in an EM instrument by leaving the electron multiplier voltage OFF on the front panel; However, the 10^{-12} and the 10^{-13} gain ranges will not be available. Opening the S2-2 switch removes the EM VOLTS message from the display screen, deactivates the electron multiplier button on the front panel, and enables the 10^{-12} and 10^{-13} gain ranges.

SWITCH	DEFINITION
S2-3	Not Used
S2-4 S2-5	Peak Finder/Interleaving — Operate in unison, see chart.

S2-4 Position	S2-5 Position	Interleaving	Peak Lock
Closed	Closed	None	No Peak Find
Open	Closed	None	Peak Find Enabled
Closed	Open	1 Channel	Peak Find Enabled
Open	Open	6 Channels	Peak Find Enabled

Interleaving permits the monitoring operations of the table mode to continue when another type of display is in use. When the Quadrex 200 is in the interleaving mode, it pauses at the end of each scan to internally update the table mode and to change to control outputs accordingly. Your interleaving choices are:

- No Interleaving
- Update 1 Channel per display scan
- Update 6 Channels per display scan

Peak Lock refers to the peak finder circuit which tracks mass peaks and gives the correct measure of peak amplitude. The peak finder circuit requires a periodic pause in

SWITCH	DEFINITION
	scanning so that the peak finder can be updated. You may wish to avoid the pause in scanning. In the "No Refresh" mode, the peak finder scans only when RESET is pressed or EMISSION is turned on; there is no pause to update the peak finder otherwise. You should restrict the "No Refresh" mode to short experiments where continuous scanning is of primary importance.
S2-6	MEM-X ~ RESET Switch. Open = Inactive, Closed = Active. When this option is active, you can operate the instrument using commands recalled from the Quadrex 200 memory with the MEM-X key; pressing the RESET button when in MEM-X changes the stored display into an active one and the previous active display is stored.

QUADREX 200 ADJUSTMENTS

There are four adjustment points matching the Quadrex 200 Sensor Control Unit to the sensor head. Normally, these adjustments need not be changed unless a different sensor head is used. However, it may be necessary to readjust the instrument to compensate for changes occurring as a result of aging.

Figure 3.4 Adjustment Points

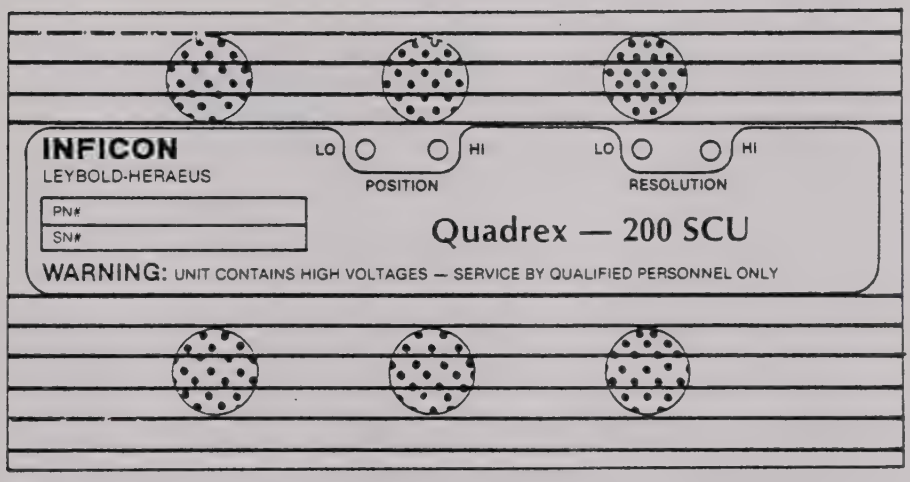


Figure 3.4 Adjustment Points

The adjustment point for all four adjustments is on the Sensor Control Unit, see Figure 3.4. The following conditions must be met prior to making any adjustments:

The unit must be operating.

The instrument must be in the Analog display mode.

The temperature must be stabilized (requires prior running time of about 1 hour).

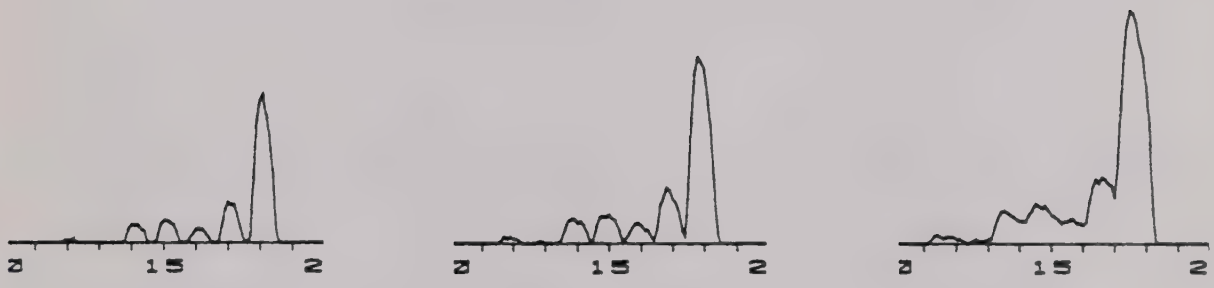
Gases yielding known mass peaks (at both the low and high mass ends of the spectrum) must be connected.

NOTE: At the low mass end air, nitrogen, or water vapor from the vacuum system are convenient. Best results for the high end of the mass spectrum come from krypton, one of the Freon gases, or a hydrocarbon such as benzene or toluene.

Peak Width Adjustments

These adjustments control the widths of the mass peaks throughout the spectrum. When the instrument is properly adjusted, the width of the peak measured at one-half of the height should be approximately ½ AMU (Figure 3.5). You must use the analog display for this adjustment. Since the peak height changes when the width adjustment is made, the vertical position at which the width measurement should be made will vary.

Figure 3.5 Peak Width Heights



Too Narrow Correct Width Too Wide

Figure 3.5 Peak Width Heights

Correct the peak width by adjusting the two screws marked RESOLUTION on the sensor control unit.

1. Select the low mass end of the spectrum using a center mass of approximately 15. Adjust the resolution screw marked "LO" until the peak width at ½h is approximately ½ AMU. Any convenient peak in this mass range may be used.

2. Choose a center mass in the high part of the mass range. Use the resolution adjusting screw marked "HI" and adjust the width of a suitable peak in the manner described above.

3. Recheck the resolution at low mass by returning to the 15 AMU center mass. You may notice that the adjustment is no longer quite correct because the high and low end adjustment interact somewhat. If necessary, repeat the high and low adjustments several times until the peak widths are correct at both ends of the spectrum.

Peak Position Adjustments

Peak position adjustments cause the maximum point of the output peak to occur at the nominal mass indicated on the display. The peaks do not have to be exactly on the mass markers because the peak finder compensates for peak shifts of ± 1/3 AMU.

The peak position can be adjusted by using the two screws marked "POSITION" on the Sensor Control Unit.

Adjust the peak position using the Analog Display which shows the true position of the peaks on the mass scale per these instructions:

1. Choose the low part of the mass range by programming a center mass of approximately 15. Select any convenient peak in this range and adjust the position screw marked "LO" so that the point of maximum amplitude of the peak lines up with the mass marker.

Figure 3.6 Peak Position Incorrect

Figure 3.7 Peak Position Correct

2. Set the center mass to a high mass part of the spectrum. Choose a convenient peak in this mass range and adjust the peak position screw marked "HI" so that the maximum amplitude of this peak lines up with the mass marker.

3. Return to the low mass part of the spectrum using the center mass of 15 AMU and check that the peaks in this region are still satisfactorily lined up with the mass markers. If not, adjust the low and high position screws again as described above. Repeat this process until both ends of the spectrum are adequately lined up with the mass markers.

   The Quadrex 200 is now adjusted.

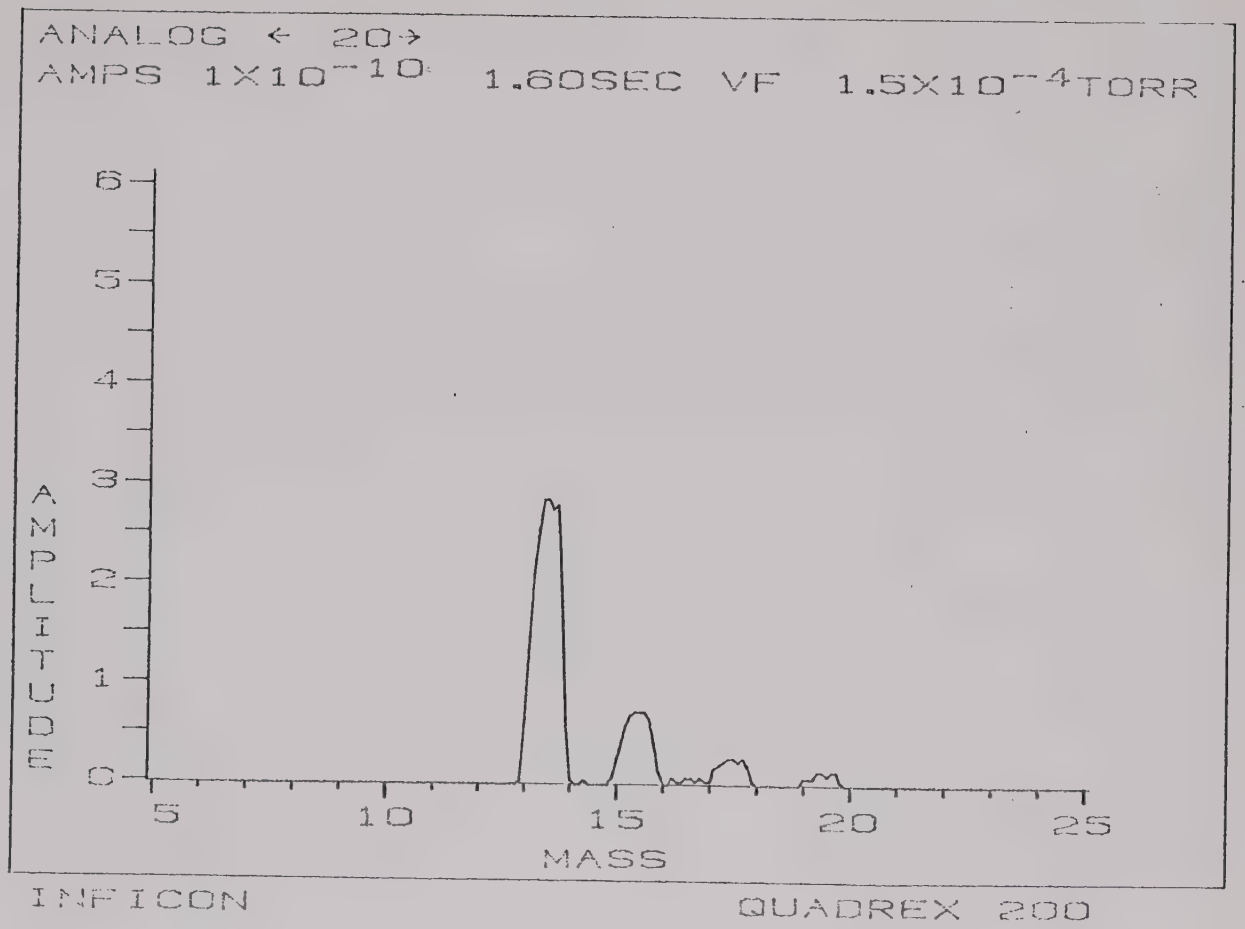


Figure 3.6 Peak Position Incorrect

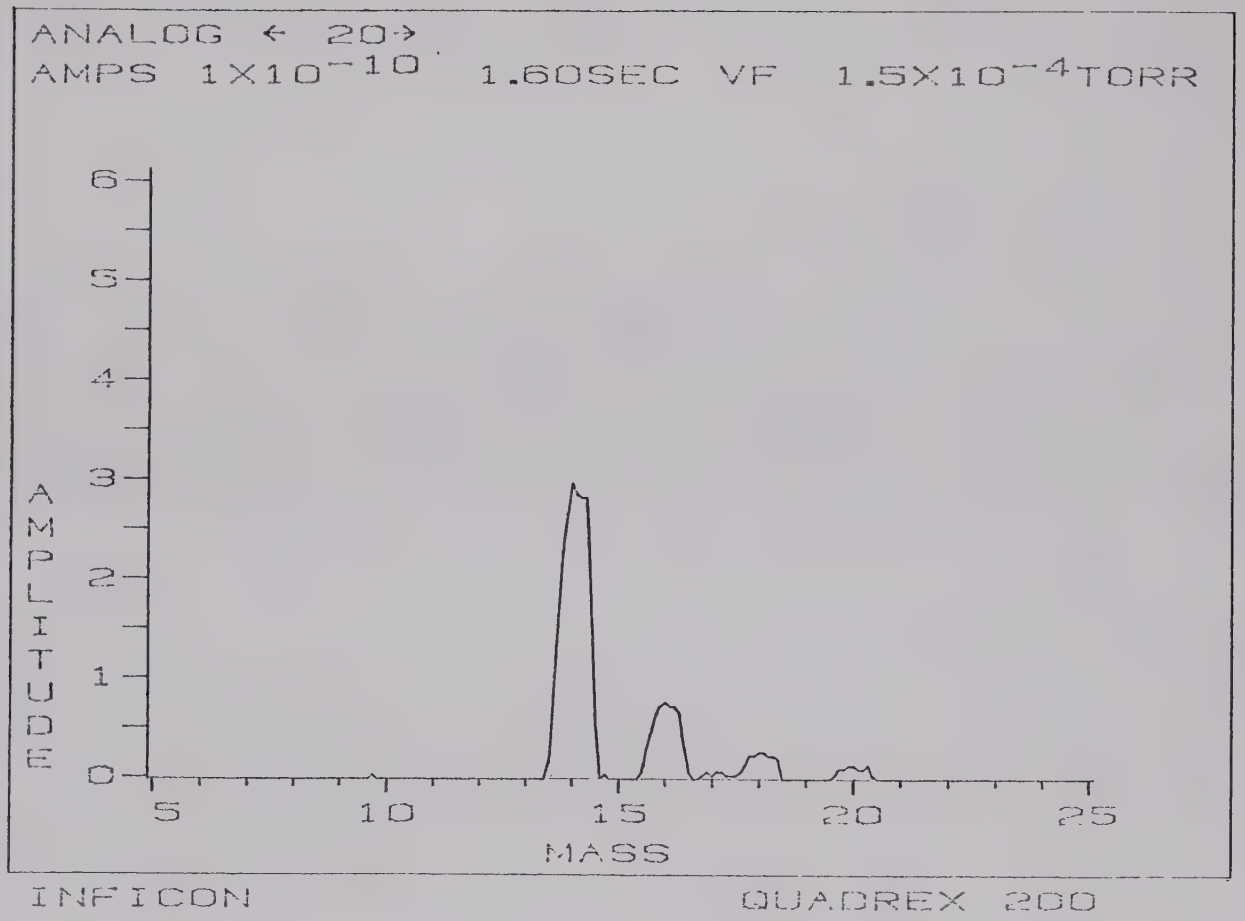


Figure 3.7 Peak Postion Correct

This section describes how the sensor head of the Quadrex 200 operates and how to interpret the resulting data. Following is a brief outline of the information in this section:

THE QUADREX 200

THEORY OF QUADRUPOLE GAS ANALYZER SENSORS
- Ion Source
- Analyzer
- Ion Detector
- Electron Multiplier

INTERPRETATION OF MASS SPECTRA
- Qualitative Characteristics of Mass Spectra
- Quantitative Characteristics of Mass Spectra
  - Ion Source Characteristics
  - Scanning Characteristics - Constant ΔM
  - Detector Characteristics
- Partial Pressure and Gas Composition Calculations

SECTION 4
THEORY AND INTERPRETATION

THE QUADREX 200

The Quadrex 200 is designed for analyzing the rarefied atmosphere in high vacuum systems. The instrument consists of a sensor which functions only in the high vacuum environment and electronic circuits which operate the sensor and display its output. The sensor analyzes the residual gases by ionizing some of the gas molecules, separating the resulting ions according to their respective masses, and measuring the quantity of ions at each mass. The masses of the various ion species (produced by the sensor) are used to identify the gas molecules from which they were created; masses are expressed in AMU's (atomic mass units) [e.g., atomic oxygen = O = 16 AMU].

The information produced by a residual gas analyzer is an important aid in the efficient utilization of a high vacuum system by, for example, indicating the presence of a leak or contaminant in the vacuum atmosphere. It can indicate the amounts of gaseous components characteristic of processes occurring within a vacuum or other vessel, and thus can be used to investigate the nature of a process or to monitor process conditions. You may develop many other specific uses for the residual gas analyzer.

A residual gas analyzer can also measure gaseous or volatile materials deliberately introduced into a high vacuum. By attaching the Quadrex 200 to a small vacuum system with a suitable controlled leak or other gas inlet device, it can be used as a medical instrument, an air pollution monitor, a chemical process monitor, or a leak detector.

THEORY OF QUADRUPOLE GAS ANALYZER SENSORS

The sensor consists of three parts: The ion source (ionizer), the analyzer (ion filter), and the ion detector. All of the parts are enclosed within the vacuum space where gas analysis measurements are made.

Figure 4.1 Sensor Construction

Ion Source (Ionizer)

In the ionizer, gas molecules of the residual atmosphere are given electrical charges by bombarding them with electrons derived from a heated filament. ("Emission current" refers to this stream of electrons.)

Principle parts of the ion source are the filament, the ion cage, and the extractor and the exit plate. The filament, a thoria-coated iridium wire, is the source of the electrons used in ionizing the gas molecules. It is heated with a dc current from the emission regulator, with the operating temperature used as the means of controlling the electron emission current. The filament operates at a nominal potential of +132V with respect to ground.

Electrons are accelerated from the filament to the ion cage with a potential difference of +80V. The nominal potential of the ion cage is 212V, with respect to ground. Because of the open structure of the ion cage, many electrons do not strike it immediately, but pass through the ion cage where they create ions upon impact with gas molecules in this zone. The repeller encloses the Ion Source and prevents the loss of electrons.

Figure 4.2 Ion Source

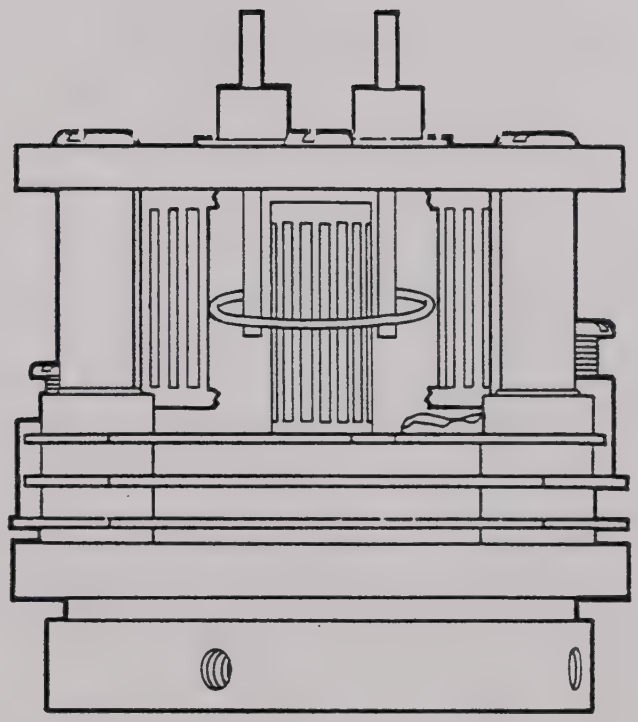


Figure 4.2 Ion Source

The third element of the ion source is the extractor. Its function is to draw ions out of the ion cage and focus them into a narrow beam. In order to produce a modulated ion beam for the ac amplifier, the extractor potential is modulated with a 500 Hz square wave so that the potential varies from 160V, corresponding to the beam-on condition, to 230V, corresponding to the beam-off condition. That is, ions are produced continuously, but during the beam-off interval they are not extracted from the ion cage.

Ions which strike the exit plate and are thus removed from the beam serve to measure the total pressure in the ion source by injecting a current into the total pressure amplifier input. As it enters the analyzer, the ion beam is decelerated by the analyzer operating potential, which is nominally +203V. Thus, the linear velocity of the ions in the analyzer corresponds to an energy of 9 eV.

Analyzer (Ion Filter)*

The charged molecules, now ions as a result of the ionizer, are accelerated electrically into the analyzer, which acts as a filter rejecting all ions except those of one specific mass/charge ratio. (Most ions contain one unit of charge; multiple charges are discussed under "Interpretation.") In the Quadrex 200 the analyzer is an electrostatic quadrupole operated by a combination of dc and RF voltages. The RF voltage magnitude and frequency determine the mass and the RF/dc ratio determines filter selectivity.

The inside radius of the quadrupole filter is 0.277 cm and the length is 12.5 cm. The filter consists of four parallel rods or poles; opposite poles are electrically connected. Ions are directed into the space between the poles, nominally parallel to the length of the poles. There the ions are separated by lateral forces resulting from the electric potentials applied to the poles.

*This discussion will explain the operation of a quadrupole mass filter in qualitative terms. Readers who are interested in a quantitative mathematic treatment are referred to one of the books on the subject, such as "Quadrupole Mass Spectrometry and Its Applications", by P. Dawson, Elsevier, 1976.

The applied potentials consist of an RF (2.2 MHz) component and a dc component with one pair of poles driven positive and the other pair negative, simultaneously. The RF component removes low mass ions from the beam; that is, ions that are of sufficiently low mass to remain in phase with the RF drive will gain energy from the field and oscillate with increasingly large amplitudes until they encounter one of the pole surfaces and are discharged.

On the other hand, high mass ions are focused by the RF component to an area close to the axis of the filter. The dc voltage is superimposed on the RF voltage to remove high mass ions. This dc field deflects the high mass ions toward the negative poles opposing the focusing effect of the RF field, so that they strike the pole surfaces and are discharged. By a suitable choice of dc to RF ratio, the filter can be made to discriminate against both high and low mass ions to the desired degree.

The mass of the ions passed by the filter is determined by the RF amplitude and the frequency. As the RF amplitude is increased, progressively heavier ions will be made to oscillate in phase with the RF field and thus gain energy to be rejected at the poles.

The quadrupole provides a convenient filter which can be tuned to the desired mass by varying the magnitude of the RF voltage; the selectivity can be adjusted by varying the dc to RF ratio.

There are two important operating characteristics of the quadrupole as an analyzer which must be discussed further. The first is the variation of selectivity with mass (i.e., with RF voltage) and the resulting variation in transmission of the filter. The second is the behavior at very low masses, where the analyzer voltages approach zero.

Scanning Characteristics

As described above, the quadrupole analyzer acts as a filter for a mixed beam of ions, rejecting those of high mass and low mass, while passing those of an intermediate mass. The selectivity of this filter is expressed in terms of resolution "R", which is numerically given by the ratio of the center mass "M" to the width "ΔM" of the pass band, both values being expressed in AMU's. Since the number of ions passed by the filter falls off gradually as the edge of the pass band is approached, the width is defined at the point where the ion current falls to some specified fraction (usually 1/2 or 1/10) of the maximum value.

While the drive circuits can be designed so that "R" varies with "M" in any desired manner, it is usually most convenient to keep "ΔM", the width of the pass region constant at a value which insures adequate separation of masses that are 1 AMU apart. This mode of scanning is called Constant ΔM. Thus "R" is proportional to "M". Since the resolution "R" increases with the mass, the output of the instrument decreases. In other words, when operated to produce constant peak widths across the spectrum, the sensitivity of the analyzer is a function of mass.

Zero Blast

When the quadrupole analyzer is tuned to very low masses, the RF and dc voltages applied to the rods approach zero. The quadrupole then ceases to act as a filter, and a large current of unseparated ions is detected. This current is called the zero blast. The zero blast is present in all quadrupole-based sensors and tends to interfere with the observation of masses 1 and 2 when many other ions are present. In some instruments, the magnitude of the zero blast is concealed by preventing the voltages from reaching zero.

Figure 4.3 Zero Blast

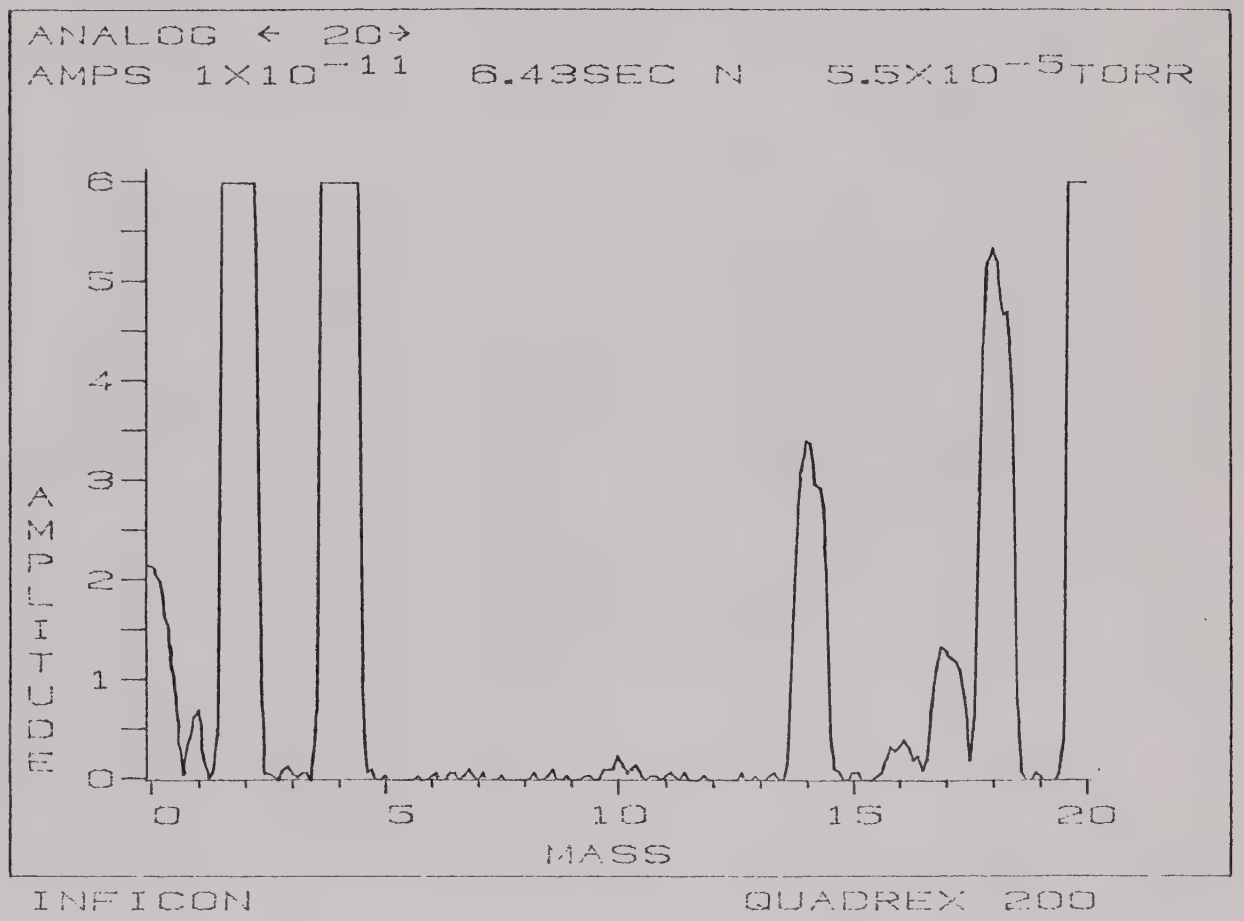


Figure 4.3 Zero Blast

Ion Detector

The ions which pass through the filter are collected on a detector and the current resulting from the ion stream is measured. The detector can be a simple collecting plate - Faraday Cup, or an Electron Multiplier which acts as a preamplifier for greater sensitivity.

As mentioned, a simple plate at ground potential serves as the detector for the Faraday Cup sensor. In this case, the current necessary to discharge the ions striking the collector becomes the input for the amplifier. Since the nominal sensitivity for nitrogen is 2×10^{-4} amps per torr, the currents will be very small at ultra-high vacuum levels (10^{-10} to 10^{-15} amps).

Electron Multiplier

The electron multiplier incorporates an amplifying detector for improved sensitivity in this case. The ions produced are allowed to impinge on the input stage electron multiplier. Since the input stage operates at approximately -2000 volts, impinging ions have high energy, producing secondary electrons.

The secondary electrons are accelerated along the length of the multiplier so that they produce additional secondary electrons. These electrons are accelerated further. Typical gain of an electron multiplier is 10^{5} at approximately 2000 volts. The output of the multiplier is then used as the input for the external amplifier which amplifies the electron current for measurement.

The gain of an electron multiplier, unlike that of conventional amplifiers, depends strongly on the operating voltage and the condition of the active surfaces. The Quadrex 200 is designed so that the operating voltage can be varied over the range 1.0 to 3.0 kilovolts to adjust the gain and compensate for aging of the multiplier.

Thus, the principle advantage of the electron multiplier over the simple Faraday Cup is its very high gain capability. The principle disadvantage is that the gain is less stable and less precisely known for quantitative measurements.

Electron Multiplier Aging

Since the Electron Multiplier performance depends on surface conditions, caution must be exercised to prevent hydrocarbon contamination.

Diffusion pumped vacuum systems must be properly trapped to reduce oil backstreaming. Turbomolecular pumped systems should be interlocked to eliminate mechanical pump oil backstreaming through a non-spinning turbo pump. Electron Multiplier gain reduction from these kinds of problems can range from 50 to more than 90%. Since the initial gain is of the order of 10^6, significant EM gain would still remain. However, with repeated instances of contamination, the multiplier will eventually require replacement.

INTERPRETATION OF THE MASS SPECTRA

Qualitative Characteristics of Mass Spectra

Each element or compound in a gas atmosphere has a characteristic mass spectrum. The spectrum will be similar, but not identical, in various instruments. The characteristics of the ionizer, the analyzer, and the detector all affect the nature of the spectrum that is produced.

The type of ionizer found in most residual gas analyzers will usually cause more than one kind of ion to be produced from a single type of gas molecule. Thus, oxygen molecules which are chemically O_2 will produce O_2+ ions and O+ ions. The O_2+ ion is called a parent ion and, for simple molecules, is usually the most abundant. Another example, water vapor, H_2O, will produce H_2O+ ions, OH+ ions, O+ ions and H+ ions. The array of peaks produced in a gas analyzer by a single substance is called a fragmentation pattern (Figure 4.4). Typical patterns of selected materials are given in Table 4-1. In order to identify the molecules that are present in the gas atmosphere by looking at the mass spectrum, you must be able to recognize these patterns. A fragmentation pattern for a mixture of gases is shown in Figure 4.5.

4.4 Fragmentation Pattern - Simple Gas

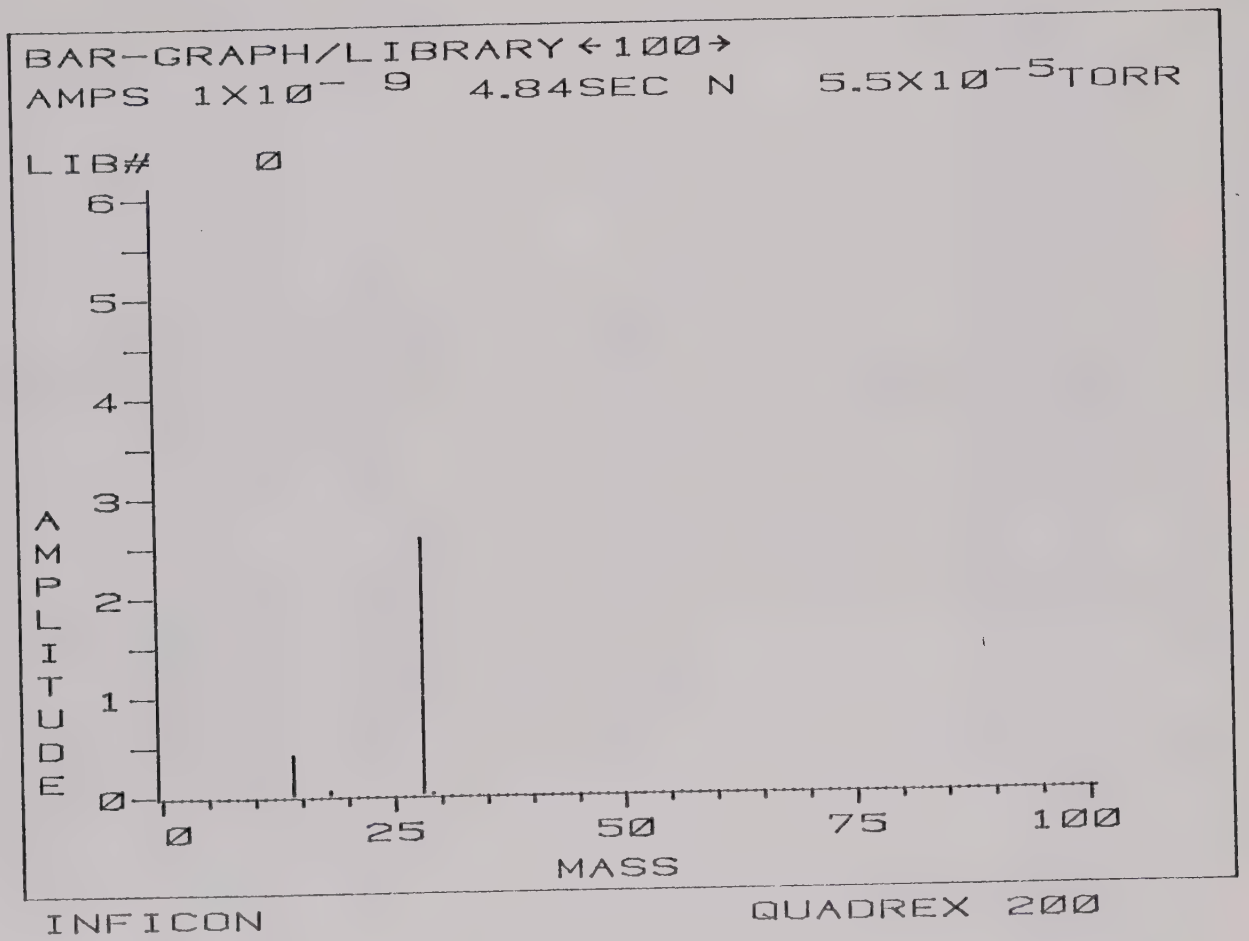


Figure 4.4 Fragmentation Pattern - Simple Gas

Beside the variety of ion types resulting from fragmentation of gas molecules, there are other characteristics of spectra that are important to recognize. Ionizers may also cause ions to be generated with more than one unit charge. These multiple-charged ions are normally produced in much smaller quantities than the single-charged ions.

Figure 4.5 Fragmentation Pattern - Complex Gas

In typical residual gas analyzers, a double-charged ion appears to have one-half the mass of the corresponding single-charged ion, since it requires one-half of the electric field to produce the same trajectory.

For example, argon produces the parent peak Ar^{+} at mass 40 and the double-charged peak Ar at mass 20. These double-charged ions may give rise to confusion when the parent ion is an odd mass number. For example, xenon has parent ions at masses 129, 131, and 132 atomic mass units. In the xenon spectrum there are also double-charged ion peaks of smaller magnitude which appear to be 64.5, 65.5, and 66 atomic mass units.

The example of xenon also shows that many materials have atoms with several isotopes; that is, there is more than one kind of atom present. For the low mass atoms, one isotope usually predominates over the others. A notable exception is chlorine, consisting of 23.5%, $C\ell^{37}$ and 75.5%, $C\ell^{35}$. The chemist uses 35.4 as an average weight of chlorine, but the mass spectrometer shows the two types of chlorine atoms separately. Isotope ratios, like fragmentation patterns, are an aid in recognizing specific materials.

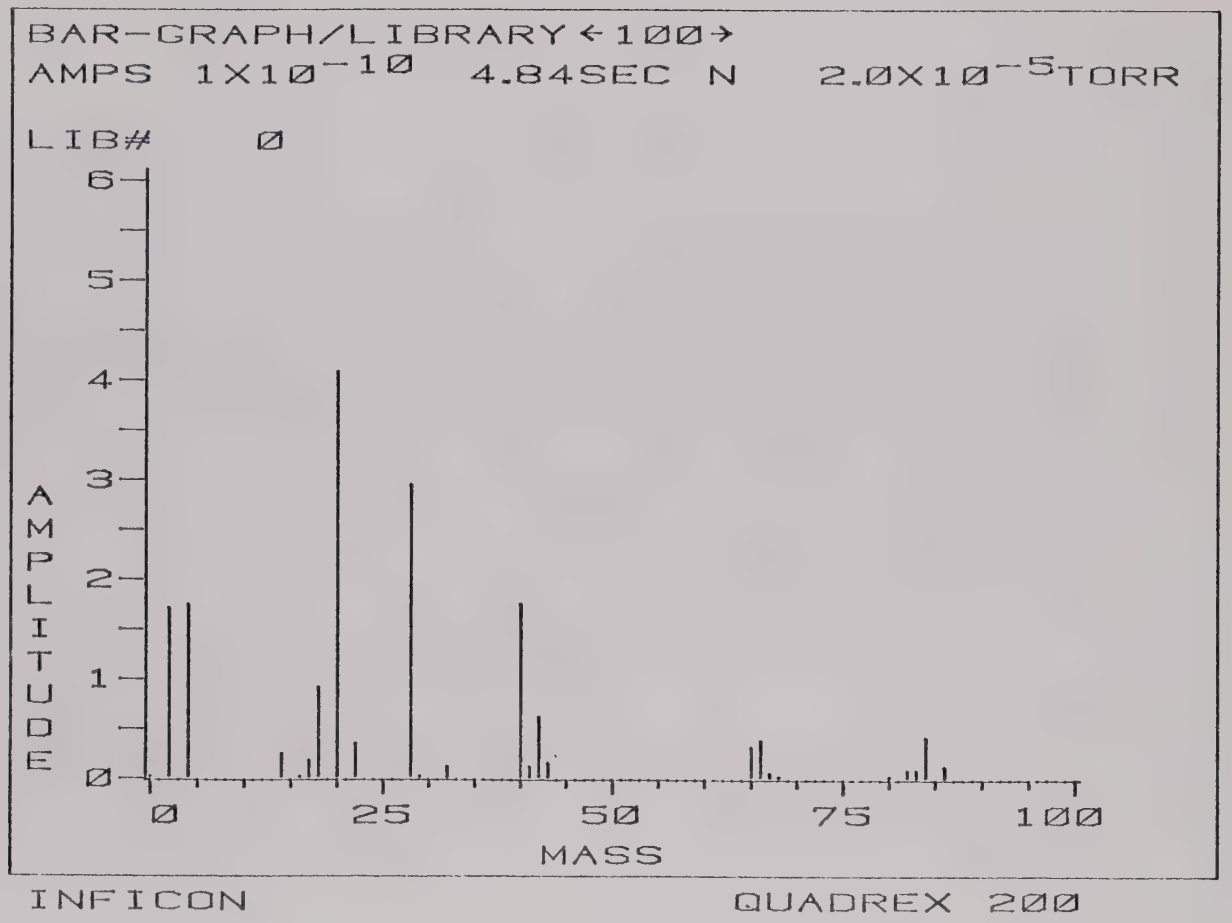


Figure 4.5 Fragmentation Pattern - Complex Gas

MASS	FF	MASS	FF	MASS	FF
Acetone $(CH_3)_2CO$		Helium He		Oxygen O_2	
43	.63	4	1.00	32	.95
58	.23			16	.05
42	.04	Hydrogen H_2			
27	.03	2	.98	Toluene $C_2H_5CH_3$	
		1	.02	91	.46
Argon Ar				92	.34
40	.88	Krypton Kr		39	.07
20	.12	84	.57	65	.05
		86	.18		
Benzene C_6H_6		82	.11	Trichlorethylene C_2HCl_3	
78	.53	83	.11	95	.22
51	.11			130	.22
52	.11	Methane CH_4		132	.21
50	.10	16	.46	97	.14
		15	.40	60	.13
Carbon Dioxide CO_2		14	.07		
44	.85	13	.04	Water H_2O	
28	.05			18	.75
16	.05	Methanol CH_3OH		17	.19
12	.02	31	.43	1	.05
		32	.31	16	.02
Carbon Monoxide CO		29	.18		
28	.91	28	.04	Xenon Xe	
12	.05			132	.26
16	.02	Neon Ne		129	.25
		20	.90	131	.20
Ethanol C_2H_5OH		22	.10	134	.10
31	.49			136	.08
45	.21	Nitrogen N_2			
27	.09	28	.94		
29	.07	14	.05		
		29	.01		

FF @ fraction of total ions that occur at the indicated mass

Table 4-1 Fragmentation Factor (Fraction of Total Ions) For Major Peaks of Selected Materials

NOTE: This table should not be confused with a spectrum library. The spectra displayed by an instrument are influenced by the mass discrimination of the quadrupole filter. Typically ions of low mass will be emphasized and ions of high mass will be diminished, relative to the abundances given in Table 4-1. A spectrum library lists the relative abundances as the instrument shows them.

In summary, then, if you use a residual gas analyzer to attempt to identify unknown substances, you must recognize three characteristics: fragmentation patterns, multiple-charged ions, and isotope ratios. Many useful identifications can be made from simple spectra; the analysis of very complicated mixtures can be more difficult.

When the residual gas analyzer is used to monitor the atmosphere for specific substances known in advance, the task of interpretation is somewhat different. In this case, select a specific mass peak characteristic of each substance to be monitored. Then make sure that this peak is unique and adequately separated from other signals representing ions of different materials.

Quantitative Characteristics of Mass Spectra

The magnitude of a signal representing a particular mass is characteristic of the number of ions produced, and therefore of the concentration of molecules of the particular substance indicated. This section describes in more detail the factors that affect the quantitative relationship between ion current output and molecular concentration.

Ion Source Characteristics

It is important to recognize that at least three effects may occur which cause the concentration of molecules within the ionizer to differ from those in the general vacuum space. To minimize these spurious effects, arrange the analyzer for maximum communication with the vacuum space.

First, the analyzer itself is a source of gas molecules because of the outgassing of its surfaces. Decrease the outgassing levels by baking the analyzer in the vacuum (prior to use) and by bombarding the ion source with electrons in the degassing operation. The outgassing rate can be reduced, but outgassing cannot be completely eliminated.

Second, it is possible that the opposite of outgassing may occur; that is, gas molecules can be captured by the surfaces of the sensor. This effect is often called "pumping." In such cases the magnitude of the signals of the gases pumped will be lower than is properly representative of the composition of the gas in the vacuum chamber. Significant temporary pumping effects will frequently occur following degassing of the ion source.

Third, reactions of the gas molecules surfaces in the analyzer can result in a change of composition. An important case of this kind is the reaction of oxygen hot filament, particularly when tungsten filaments are used. The typical result is that the quantity of oxygen molecules detected is inordinately small and that CO molecules are present due to the reaction

of oxygen with carbon in the hot filament. (The Quadrex 200 uses thoria-coated iridium filament material and is relatively free from this effect.) Thus, the quantitative measurement of highly active gases is relatively difficult and less precise than the measurement of less active gases.

Residual gas analyzers are also characterized by varying degrees of mass discrimination; that is, the sensitivity of the instrument is a function of mass.

Ion sources show mass discrimination because the various kinds of molecules offer different degrees of difficulty in ionization. Generally, heavy large molecules are ionized more readily than light, small molecules. For similar molecules the ion yield is normally proportional to the number of electrons in orbit. Relative values of ion yield for selected molecules are given in Table 4-2 (compiled and published by NASA, June 1969).

Substance	Formula	Relative Ionization Gauge Sensitivity, S/S_{N_2}	Substance	Formula	Relative Ionization Gauge Sensitivity, S/S_{N_2}
Acetone	$(CH_3)_2CO$	3.6	Hydrogen chloride	HCl	1.6
Air		1.0	Hydrogen floride	HF	1.4
Ammonia	NH_3	1.3	Hydrogen iodide	HI	3.1
Argon	Ar	1.2	Hydrogen sulfide	H_2S	2.2
Benzene	C_6H_6	5.9	Iodine	I_2	
Benzoic acid	C_6H_5COOH	5.5	Krypton	Kr	1.7
Bromine	BR	3.8	Lithium	Li	1.9
Butane	C_4H_{10}	4.9	Methane	CH_4	1.6
Carbon dioxide	CO_2	1.4	Methanol	CH_3OH	1.8
Carbon disulfide	CS_2	4.8	Neon	Ne	0.23
Carbon monoxide	CO	1.05	Nitrogen	N_2	1.0
Carbon tetrachloride	CCl_4	6.0	Nitric oxide	NO	1.2
Chlorobenzene	C_6H_5Cl	7.0	Nitrous oxide	N_2O	1.7
Chloroethane	C_2H_5Cl	4.0	Oxygen	O_2	1.0
Chloroform	$CHCl_3$	4.8	n-Pentane	C_5H_{12}	6.0
Chloromethane	CH_3Cl	3.1	Phenol	C_6H_5OH	6.2
Cyclohexylene	C_6H_{12}	6.4	Phosphine	PH_3	2.6
Deuterium	D_2	0.35	Propane	C_3H_8	3.7
Dichlorodifloromethane	CCl_2F_2	2.7	Silver perchiorate	$AgClO_4$	3.6
Dichloromethane	CH_2Cl_2	3.7	Stannic iodide	SnI_4	6.7
Dinitrobenzene	$C_6H_4(NO_2)_2$	7.8	Sulfur dioxide	SO_2	2.1
Ethane	C_2H_6	2.6	Sulfur hexafloride	SF_6	2.3
Ethanol	C_2H_5OH	3.6	Toluene	$C_6H_5CH_3$	6.8
Ethylene oxide	$(CH_2)_2O$	2.5	Trinitrobenzene	$C_6H_3(NO_2)_3$	9.0
Helium	He	0.14	Water	H_2O	1.0
Hexane	C_6H_{14}	6.6	Xenon	Xe	3.0
Hydrogen	H_2	0.44	Xylene	$C_6H_4(CH_3)_2$	7.8

Table 4-2 Ionization Probability Table

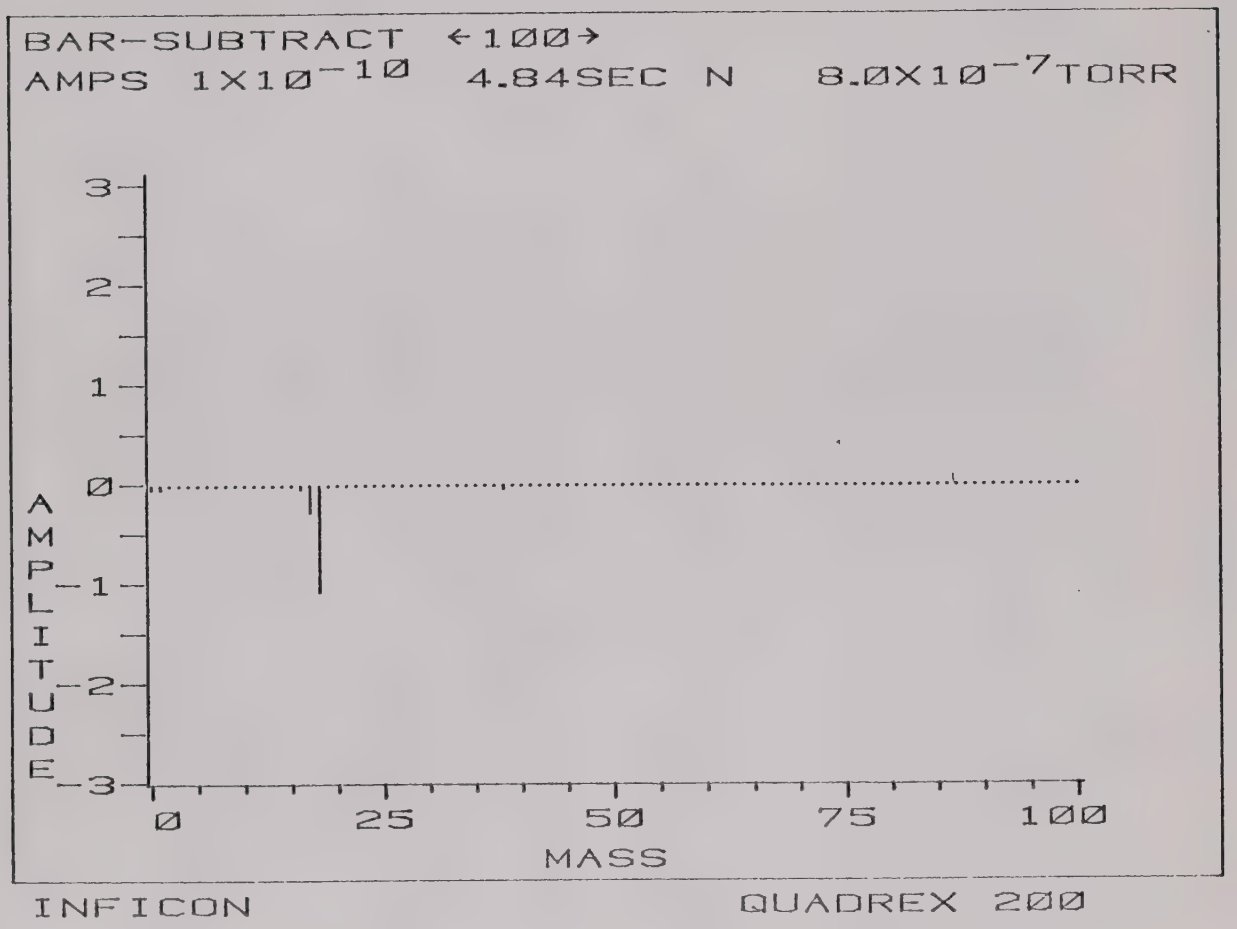


Figure 2.12 Bar Subtract/Water Peak Display

Scanning Characteristics - Constant ΔM

Quadrupole filters can also exhibit mass discrimination characteristics depending on how the control voltages are varied during the sweep through the mass range. Most instruments are designed to operate with a constant peak width (Constant ΔM) which results in a resolution that is proportional to the mass during the sweep. This characteristic provides a good degree of separation throughout the mass spectrum, but the ion transmission decreases with increasing mass.

Detector Characteristics

Faraday Cup detectors are normally considered to have no mass discrimination. Electron multiplier detectors, however, have varying degrees of mass discrimination, depending on their design characteristics. The electron multiplier in the Quadrex 200 has very little mass discrimination.

In summary, the quantitative measurement of gaseous materials with the mass spectrometer requires careful attention to interactions of the material with the spectrometer itself and to the mass discrimination of the ion source, analyzer, and detector. In the Quadrex 200 analyzer the mass discrimination in the detector can be quite small, but the varying ionization efficiency for different substances in the analyzer and the transmission characteristics of the analyzer are still important to recognize.

Partial Pressures and Gas Composition Calculation

The quantitative characteristics of the Quadrex 200 may be used for measurement of the absolute pressure of a component in a mixture of gases (the "partial pressure") or the relative amount of each gas expressed as a percentage of the total.

The following symbols will be used:

PP_A = Partial pressure of a given substance "A" in a gas mixture - torr.

I_{AB} = Current output of the Quadrex 200 sensor, signal amplitude of a mass peak, "B" resulting from substance "A".

FF_{AB}= Fragmentation factor, fraction of total ions from substance "A" having mass "B" see Table 4.1 (page 4-10).

FF_{N28}= Fragmentation factor for N_2^+ ions from nitrogen (typically .90 to .95 and often taken as 1.0).

XF_A = Ionization Probability, relative yield of ions from substance "A" compared to nitrogen at the same partial pressure, see Table 4.2 (page 4-12).

TF_B = Transmission factor, the number of ions of mass "B" that pass through the analyzer, relative to ions of mass 28. TF = (28/M) (nominal).

DF_{AF} = Detection factor, the relative current per ion at mass "B" compared to nitrogen ions at mass 28. For the Quadrex 200 with Faraday Cup, DF = 1. For the Quadrex 200 with electron multiplier, DF = 1 approximately.

S = Sensitivity for nitrogen, output current (at mass 28) per unit absolute pressure for pure nitrogen-amp/torr. For the Quadrex 200 with Faraday Cup, $S = 2 \times 10^{-4}$ amp/torr (nominal). For the Quadrex 200 with electron multiplier, S varies widely depending on the operating voltage and condition of the multiplier. For a new sensor S = 1 at a voltage typically in the 1800-2000 range.

Then we can say, the partial pressure of substance "A" indicated by the amplitude (I) of signal at mass "B" is

$$PP_A = (I_{AB} \times FF_{N28})/(FF_{AB} \times XF_A \times TF_B \times DF_{AB} \times S) \quad (1)$$

This equation is quite general and holds true for all mass spectrometers.

The constants for these equations can be obtained from tables or, for best accuracy, measured for each instrument (instruments will not be identical). Some values of FF are given in Table 4-1. For more mass spectrometric reference information, contact American society for Testing and Material, 1916 Race Street, Philadelphia, PA 19103, Phone (215) 299-5900. For more spectra data refer to the following:

Index of Mass Spectral Data, ASTM, Phila.

Compilation of Mass Spectra Data, Cornu, A and Massot, R., Heydon and Sons Ltd., London

Relative cross section (XF) is given in Table 4-2 for some substances of interest. You can find additional data in many texts on vacuum technology such as the following:

Scientific Foundations of Vacuum Technique, Second Edition, Dushman, S. (Revised by Lafferty, J.M.), Wiley, New York.

Physical Basis of Ultra-High Vacuum, Redhead, P.A., et al, Chapman-Hall, 1968.

The Table mode provides a means where the constants for each substance may be factored into the measurements by the Quadrex 200, permitting direct readout. In this case, determine a multiplying factor "C" as follows:

$$C = 1/D \qquad (2)$$

where D = denominator in Equation (1).

Write "C" in the form $X.X \times 10^{YY}$. Insert the number X.X in the CALIB position. The number in the value column can then be read directly. The exponent is determined by subtracting YY from the number shown in the GAIN column.

Example:

Suppose argon is measured at mass 40. FF = 0.88, XF = 1.2, TF = 28/40, DF = 1, S = 2×10^{-4} (Faraday Cup sensor). Then from Equation (1),

$PP = I/[0.88\ (1.2)\ 0.7\ (2 \times 10^{-4})] = I/(1.54 \times 10^{-4}) = I \times .65 \times 10^{4}$

Set CALIB at 0.7

Operate the instrument. Suppose the reading is value = 2.8, gain = 11. The exponent will be 11 - 4 = 7. The partial pressure of argon is 2.8×10^{-7} torr.

Instead of partial pressure, it is sometimes of interest to determine the composition of a gas mixture in terms of percentages. In a mixture consisting of components A, B, C, ---, the percentage of "A" is the ratio of its partial pressure to the total pressure:

$$\%A = (PP)_A/[(PP)_A + (PP)_B + (PP)_C + \text{---}] \times 100 \qquad (3)$$

Obtain the total pressure by measuring all significant partial pressures and adding them or by using a total pressure gauge. Note, however, that ionization gauges do not measure true pressures of mixtures, since they are subject to varying ionization cross sections just as gas analyzers are.

The Quadrex 200 can be programmed to read in percentage composition directly with the Table mode, provided the total pressure remains constant. This requirement will not usually be met when measuring the constituents in a vacuum system but will often exist when sampling from a source at atmospheric pressure through an inlet system with a molecular leak. In the latter case the easiest method of calibration is to use a mixture of known composition and simply insert calibration factors that result in correct value readings.

Table 4-3 Spectra Interpretation Guide

AMU NO.	CHEMICAL SYMBOL	SOURCES (F = Fragment, P = Parent Ion, DI = Doubly Ionized)	
1	H	Water F or Hydrogen F	
2	H_2, D	Hydrogen, Deuterium (H^2)	
3	HD, H^3	Hydrogen-Deuterium, Tritium (H^3)	
4	He	Helium	
5		No known elements	
6	C^{++}	Doubly Ionized C^{12}	Rare
7	N^{++}	DI N^{14}	Rare
8	O^{++}	DI O^{16}	Rare
9		No known elements	
10	Ne^{++}	DI Ne^{20}	Rare
11	Ne^{++}	DI Ne^{22}	Rare
12	C	Carbon, Carbon Monoxide F, Carbon Dioxide F	
13	CH, C^{13}	Methane F, Carbon Isotope	
14	N, CH_2	Nitrogen, Methane F or Note 1	
15	CH_3	Methane F or Note 1	
16	O, CH_4, NH_2	Oxygen or Carbon Monoxide F, Methane P, Ammonia F	
17	OH, NH_3	Water F, Ammonia P	
18	H_2O	Water P	
19	F	Fluorine or Freon F	
20	Ar^{++}, Ne, HF	DI Argon, Neon Hydrofluoric acid	
21			
22	Ne^{22}	Neon isotope	
23			
24	C_2	See Note 1	
25	C_2H	See Note 1	
26	C_2H_2, CN	See Note 1, Hydrogen Cyanide F	
27	C_2H_3, Al, HCN	See Note 1, Aluminum, Hydrogen Cyanide	
28	N_2,CO, C_2H_4, Si	Nitrogen, Carbon Monoxide, Ethylene P, Silicon	
29	CH_3CH_2	Ethane F or Ethanol F or Isopropyl alcohol F	
30	C_2H_6, NO	Ethane P, Nitric Oxide	
31	P, CH_2OH, CF	Phosphorus, Methanol F, Ethanol F, Freon F	
32	O_2, CH_3OH, S	Oxygen, Methanol P, Sulfur	
33	HS	Hydrogen Sulfide F	
34	*H_2S, S^{34}	Hydrogen Sulfide P, Sulfur isotope	
35	*Cl	Chlorine isotope, See Note 2	
36	*HCl, Ar^{36}	Hydrochloric acid, Argon isotope	
37	*Cl^{37}	Chlorine isotope, See Note 2	
38	HCl^{37}	Hydrochloric acid or See Note 2	
39	C_3H_3	See Note 3	
40	Ar, C_3H_4	Argon, See Note 1	
41	C_3H_5	See Note 1	
42	C_3H_6	See Note 1	
43	C_3H_7, CH_3CO	Note 1, Acetone F or Methyl Ethyl Ketone F	
44	CO_2, C_3H_8	Carbon dioxide, See Note 3	
45	CH_3CH_2O	Ethanol F or Isopropyl alcohol F	
46	CH_3CH_2OH	Ethanol P	
47	CCl^{35}	See Note 2	
48	$HCCl^{35}$, SO	See Note 2, Sulfur Dioxide F	
49	CCl^{37}, SiOH	See Note 2, pump oil F	
50	CCl^{37}, CF_2, C_4H_2	See Note 2, Freon F, Note 3	

NOTE 1
Fragments of several hydrocarbons, such as mechanical pump oil, diffusion pump oil, vacuum grease, cutting oil, and organic solvents.

NOTE 2
Fragments of several chlorinated hydrocarbons, such as carbon tetrachloride, trichloroethylene and many Freons.

NOTE 3
Fragments from both straight chain hydrocarbons and benzene ring hydrocarbons.

*See Isotopic Ratio Chart on back.

Table 4-4 Isotopic Ratio Chart

Element	Mass No.	Relative Abundance
H	1	99.985
	2	0.015
He	3	0.00013
	4	~100.0
B	10	19.78
	11	80.22
C	12	98.892
	13	1.108
N	14	99.63
	15	0.37
O	16	99.759
	17	0.0374
	18	0.2039
F	19	100.0
Ne	20	90.92
	21	0.257
	22	8.82
Na	23	100.0
Al	27	100.0
Si	28	92.27
	29	4.68
	30	3.05
P	31	100.0
S	32	95.06
	33	0.74
	34	4.18
	36	0.016
Cl	35	75.4
	37	24.6
Ar	36	0.337
	38	0.063
	40	99.600

The partial pressure display mode of the Quadrex 200 is obtained by using the instrument to solve Equation (1) for specific gas species. For this purpose, the constants in the equation are grouped as follows:

$$PP_a = I_{ab} \times [FF_{n28}/S] \times [FF_{ab} \times XF_a\ DFab)] \times [1/TF_b] \qquad (4)$$

This expression can be condensed into

$$PP_{ab} = I_{ab} \times SF \times MF_{ab} \times TR_b \qquad (5)$$

In Equation 5, SF is the basic instrument sensitivity and is not dependent on the gas species being measured. The numerical value of SF is expressed in torr/milliamp and is determined experimentally by establishing a known pressure of nitrogen gas and measuring the current at mass 28.

$$SF = P_{N2}(\text{torr})/(1000 \times I_{28}(\text{amps}) \qquad (6)$$

The nominal value of SF for Faraday Cup heads is 5.0 E-0. The nominal value for EM heads operating at maximum specified gain (100 amp/torr) is 10.0 E-6. More commonly, EM heads will be operated at a sensitivity of about 1 amp/torr, using a voltage of 1800-2000 volts; in this case, SF is 10.0 E-4.

In Equation 5, MF represents a set of material-dependent factors which are largely independent of the instrument characteristics. For practical purposes, DF = 1 and MF can be calculated from tabulated values, as follows:

$$MF_{ab} = 1/(XF_a \times FF_{ab}) \qquad (7)$$

MF can also be determined by direct experiment, when best accuracy is needed.

For comparison with instruments which do not correct for material-dependent effects, MF can be set to 1.000 (nitrogen equivalent).

The remaining factor in Equation 5, $(1/TF_b)$ is internally generated in the instrument.

NOTE: Make sure that the peak chosen to represent a given material does not include significant contributions from other gas species having fragments of the same mass.

Section 5 includes detailed information and schematics which define the Quadrex 200 electronic circuitry.

5.1 ELECTRONIC CIRCUITRY

The Operator's Console contains the power supply, control and measurement card, CPU card, and video generator card. Optional cards, I/O Relay Module and IEEE-488 Module, also plug into this unit.

The Sensor Control Unit contains the sensor bias regulator board, RF/dc control board, and preamplifier.

Each card is described in this section.

Figure 5.1 Quadrex System

Figure 5.2

Figure 5-3

5.2 POWER SUPPLY (017-380)

The power supply generates the 6 voltages needed for proper operation of the Quadrex 200.

1. 5V @ 4 amps for Logic
2. 12V @ 2.5 amps for the CRT
3. 24V @ 2.5 amps for the RF/DC Gen & for the Sensor Filament Circuits
4. 350V @ 35 ma for the Sensor Bias Circuits
5. +18V @ 350 ma for the Linear Circuits
6. -18V @ 350 ma for the Linear Circuits

The 5, 12, and 24 volt regulators all are driven from an unregulated 28V dc Bus. The 5 volt switching regulator consists of control circuit Z3, power switching network Q25, and inductor L2. Output voltage is determined by the internal 5V reference of Z3 and divider network R36 and R38. Current limit protection is accomplished by comparing the voltage across current sense resistor R34 to the fixed voltage drop of diode CR12. Output noise is limited by L4 and C21.

Operation of the 12 volt switcher is similar to the 5 volt switcher with the exception of the voltage and current-sensing element values. The 12 volt control circuit Z4 is also slaved to the 5 volt control circuit Z3 such that they both operate at the same frequency and phase. This insures consistent noise and regulation performance from both regulators. Both regulators also employ slow start networks R37-C29 and R46-C35 to reduce current surges on power turn on.

The 24 volt regulator VR4 is a linear regulator whose output voltage is determined by the ratio of R21 to R22. This regulator is switched to approximately 1.2V (EMISSION OFF) by shorting R22 with control transistor Q4. Transistor Q4 is driven by control logic Z2. This logic requires that a watchdog pulse train be present (10 p.p.s.) and the 24VON signal be present in order to turn Q4 off and cause regulator VR4 to operate at 24 volts. The watchdog feature insures protection of the electronics if the software or CPU fails to operate properly. The 24 volt regulator is only operational when the emission switch on the front panel is activated. Any system malfunctions will cause the 24 volts to be turned off, thus protecting the sensor and electronics.

The 350 volt regulator is a switching type shunt flyback circuit consisting of control element Z1, inductor L1, FET switch Q1, and clamp circuit CR1-C1. Inductor L1 is charged by turning FET switch Q1 on. When Q1 turns off, the inductor field collapses causing a high voltage pulse on its drain. This pulse is coupled to the output capacitor C1 by switching diode CR1. The capacitor voltage rises until enough feedback voltage via R1 is present to cause the control IC to reduce the FET switch on-time.

Since this circuit is driven from the regulated 24V supply, high voltage is only present when the 24 volt supply is turned on. A slow start circuit R8-C3 limits current surges upon turn on.

Linear regulators VR1 and VR2 supply the ±18 volts for the Analog sections of the instrument. These regulators are driven from a 36V CT bridge rectifier and filter. The negative full wave rectified ac is sampled via CR2 to provide a line voltage failure indication. Z2 (along with Q3) is both a threshold and pulse omission detector. If line voltage pulses don't occur for a duration longer than 100 ms or the line voltage falls below 85V rms a power fail signal is sent to the CPU via Z2 pin 6.

Figure 5.4 Power Supply

Figure 5.5 Power Supply Board

5.3 CENTRAL PROCESSOR (017-330)

The CPU board controls the entire operation of the Quadrex 200. Firmware contained in Read Only Memories Z2 through Z5 is interpreted by the CPU chip Z1 and directs all instrument activity. A multi-task operating system allows several instrument functions to occur concurrently. Static ram Z6 provides the necessary operating system variable storage area. CMOS static ram Z28, provides program variable and data retention during power off conditions.

Address, control, and data bus buffers Z22, Z33, Z34, Z26 provide isolation between the main CPU and external logic. Z15 provides the CPU clock and also generates a secondary frequency used to derive various baud rates for any serial communications activity.

This activity is controlled by SIO chip Z23. Z32 is a multi-channel interrupt controller and timer used to derive all system timing. Two 4 x 5 keyboard array scanners Z29 and Z30 provide interaction with the instrument front panel. Status switch S2 and input port Z25 determine various operating modes within the Quadrex 200 firmware structure. Memory address decoding is provided by Z17 and Z18. I/O address decoding is provided by Z10 and Z18. CMOS latch circuitry Z16 and Q1 provide memory protection of the CMOS rams during power up and down cycles.

Figure 5.6 Central Processor

Figure 5.7 Central Processor Board

5.4 VIDEO GENERATOR (017-320)

The video board resident in the Quadrex 200 contains a second CPU and memory structure operating in a DMA mode with the main CPU. Through the use of a high level command structure, instructions are passed from the main CPU to the video board CPU in a common "mailbox" memory area. The main CPU is then free to perform other tasks while the video CPU interprets and executes the required video functions.

The shared memory is contained in ram Z19. DMA request logic Z17, Z11 deactivates the video CPU and places the video bus system on the main CPU bus through buffers Z9, Z30, Z31. ROM Z14 contains all video operating firmware. CRT controller Z2 generates all Sync and video memory address control needed to produce stable displays.

Address multiplexers Z20, Z21, Z22, and Z27 control addressing between the CPU and CRT controller.

Data from the dynamic video memory Z3, Z7, Z10, Z16, Z23, Z24, Z28, and Z34 is converted to dot information by shift register Z15. This dot data is combined with the Sync data by Z18. Q2 and Q3 convert the logic data into analog levels. Dynamic memory timing is provided by Z25, Z26, Z32, and Z33. This timing is derived from oscillator Y2. Z5 and Z18 perform the syncronization between the dynamic memory timing and the CPU timing.

Figure 5.8 Video Generator

Figure 5.9 Video Board

5.5 MEASUREMENT CONTROL (901-312)

The measurement control card contains all the circuitry necessary to operate the Sensor Control Unit (SCU), and to generate the audible alarm in the leak check mode.

A synchronous demodulator consisting of Z17 and Z18 converts the 500 Hz ion current signal from the preamplifier into a dc value. This dc value is routed to a 12 bit A to D converter Z7, through analog multiplexer Z17 and track and hold amplifier Z13. The total pressure signal from the bias regulator board is routed to Z7 in the same manner.

The preamplifier gain range is selected by output port Z1. All S.C.U. status information is detected by input port Z5. Output port Z10 generates main system control signals, emission on, degas on, multiplexer control, pen control and power supply watchdog.

8 bit D to A converters, Z12, Z6, Z3 and Z16 generate the XY recorder, electron multiplier supply, and test mode analog control voltages. Z8 is a 12 bit D to A converter that along with Z14 generates the 0 to 10 volt mass command signal.

Z22, and Z23 provide the audio amplitude and frequency control to audio oscillator Z24. Q3 and Q4 form a push pull emitter follower that drives speaker unit LS1.

Z19 provides the 500 Hz square wave for the modulator/demodulator circuitry. Z11 is a bus buffer while Z20 and Z21 provide the address decoding for the converters and I/O ports. Regulators VR1 and VR2 provide needed operating voltages.

Figure 5.10 Measurement Control

Figure 5.11 Measurement Control Board

5.6 BIAS REGULATOR (901-322)

The bias regulator provides all the potentials necessary for proper operation of the ionizer section of the quadrupole analyzer. The electron multiplier supply is also here on EM units. A log amplifier provides a means for determining total system pressure. The electronics operate as follows:

The anode regulator consisting of Q14, 15, 16, and Z4 provides 212 volts to the ionizer anode. A lens supply consisting of resistive divider string R83, R69, R70, and R85 is modulated by opto isolator Z6 between approximately 150V and approximately 230V. The modulation frequency is 500 Hz. A current sink consisting of Q5, Q6, and Z4 constantly attempts to pull 2 mA from the ionizer filament (cathode) to ground.

A voltage comparator Q3 operating at 132 volts monitors the cathode dc potential and controls switching regulator Z2. This regulator then provides enough filament power to maintain the correct cathode potential. Z1 limits the maximum allowable dc filament voltage obtainable from flyback transformer T1 and rectifier CR1.

During a degas condition diode CR13 sets the anode regulator to 315 volts. Q7 CR10 sets the current sink to 15 mA. The cathode voltage comparator is set to 25V via Q2. This system provides additional source energy to outgas the quadrupole ion source.

A logarithmic amplifier Z5-CR16 and differencing network C17-Z5 provide a 5 decade compression of the total ion current generated by the analyzer.

The optional electron multiplier supply consists of module PS1 and Q11-Z5. The high voltage output is sampled by R78 and compared to the desired operating voltage by integrator amplifier Z5. This amplifier turns Q11 on until the proper output voltage is achieved.

DIAGRAM ON REVERSE SIDE

Figure 5.12 Bias Regulator

Figure 5.13 Mass Filter Bias Regulator

5.7 RF/DC GENERATOR (901-302)

This board contains the circuitry necessary to generate and control the high voltage RF and DC potentials needed to operate the quadrupole analyzer. The RF voltage is generated by transformer T2 operating as the tuned tank circuit of the class C power amplifier Q3. The RF output signal is sampled via capacitor C4, and clipped and amplified by CR1, CR2, and Q1. The output of Q1 provides the injection signal for the phase locked oscillator system Z1. The use of a phase lock loop drive system insures that the RF generator will always operate at resonance and thus at maximum efficiency.

The output of PLO stage Z1 drives the amplitude drive control stage Q5. The output amplitude of Q5 is controlled by the emitter current set by loop error amplifier Z2. Q6 functions as a buffer stage and Q2 acts as a current limiter on the output FCT Q3.

The DC rod potentials are derived by sampling a portion of the RF voltage and rectifying it via clamp diodes CR5, 6, 15 and 16. Active bias for the clamp diodes is provided by 2 sections of op amp Z3. The clamped RF voltages are filtered by RC networks R5-C9 and R45-C23 and each is fed into part of the split secondary of RF transformer T2. The proper RF/DC ratio is set by the resistance of network R74, R75, R77 and R79, and feed resistors R5 and R45. RF amplitude is measured by converting the positive rod voltage into a proportional current. Z3 and Q9 accomplish this. This current is compared to the mass command current set by Z2-R24 via the integrator section of Z2. The integrator increases or decreases the RF drive voltage to Q3 until the command and amplitude currents match.

A boosted plus/minus 9 volt supply consisting of CR12 and CR13 provides operating voltages for Z3. This supply operates approximately 203V above ground. The analyzer ion energy is set via CR13. Q8 is a current sink circuit operating at approximately 5MA that provides a constant load for the RF/DC boost electronics.

Figure 5.14 RF/DC Generator

Figure 5.15 RF/DC Control Board

5.8 PREAMPLIFIER (017-390)

The amplifier electronics converts the 500 Hz ion current generated by the sensor into measurable voltage levels. Z2 is a low noise current to voltage stage with a gain of 2×10^7 volts/amp. Z1 is a programmable stage with a gain of either 1 or 3. The test mode signal is introduced through this stage when requested. Z3 has selectable gains of 1, 10, 100, and 1000. Z5 is a variable gain selectable bandwidth amplifier with a center frequency of 500 Hz. This stage has gains of 1, 10, or 100 and bandwidths down to 10 Hz. Regulators VR3 and VR4 provide power for the gain stages.

Figure 5.16 Preamplifier

Figure 5.17 Preamplifier Board

5.9 ANALOG OUTPUT OPTION (017-360)

The analog option provides the user a means for obtaining individual amplitude information on the six Table Mode channels. A 0 to +10V signal is provided for each measurement channel.

The electronics consists of a data bus buffer Z10, address decoder Z11, and 8 bit latching digital to analog converters Z1 through Z9. Converters Z4 and Z9 provide active mass and amplitude data for all channels and modes. Output impedance is approximately 500 ohms.

Figure 5.18 Analog Output Option

Figure 5.19 Analog Option Board

5.10 RELAY OUTPUT OPTION (017-340)

The relay option provides the user with the means for obtaining programmable set point information from the Quadrex 200. Each of the six channels of the Table Mode has a specific relay designation. When the measured value is greater than the set point the relay is energized (contacts closed). Relay operations may be disabled and/or re-enabled by activating the front panel relay switch. Relay (7) contacts are closed whenever the limit relay operations are inhibited. Relay (8) is an instrument status relay indicating all sensor parameters are within proper bounds and that valid data is being measured.

The electronics consists of address decoder Z3, 8 bit latch Z2, relay driver Z1 and 8 relays K1 through K8. Relay ratings are 120V/100VA.

Figure 5.20 Relay Output Option

Figure 5.21 Relay Option Board

INTERCONNECTING CABLES (DRAWINGS)

Page	Drawing Title	Drawing Number
5-26	Assembly Control Cable	D017-121
5-27	Assembly Emission Cable	D017-122
5-28	Assembly Signal Cable	D017-123
5-29	Assembly Plotter Cable	D017-124

Figure 5.22 Assembly Control Cable

Figure 5.23 Assembly Emission Cable

Figure 5.24 Assembly Signal Cable

Figure 5.25 Assembly Plotter Cable

5.11 CRT DRIVER CARD

This assembly is not manufactured by Inficon. Information supplied here is for reference. Note that the card is modified for brightness control with an external potentiometer.

5.12 IEEE 488/SERIAL PLOTTER

The IEEE 488 card contains the hardware and software necessary to interface a Quadrex 200 to the IEEE 488 communications bus as a talker/listener device. This card also contains the software necessary to interface with the RS232 Digital Plotter as described in the Digital Plotter Option Section.

The hardware consists of a Data Bus Buffer Z9, Address Buffers Z10 and Z11 and Control Bus Buffer Z12. Address decoding and interrupt bus control is provided by Z5 and Z6. A programmable input/output device Z2 provides interrupt vectoring and reads the Device Address switches resident on the rear panel of the card. A programmable 488 Talker/Listener Device Z3, provides the communication control between the CPU and the 488 Bus. 488 Bus Drivers Z4 and Z8 provide proper voltage levels and timing between data transfers.

The 488 option when installed has priority over the RS232 option and will disable it unless the 488 system is disabled through the device address switch. Switches 1 through 5 set the Binary Device Address and Switch 8 is the Enable 488 function. The switch employs positive logic sense.

Figure 5.26 IEEE 488/Serial Plotter Diagram

5.13 I/O RELAY 017-420

The I/O Relay Option provides the user with the means for operating the control functions of the Quadrex 200 remotely. The functions include individual ON and OFF commands for Emission, Degas, Electron Multiplier, and Relay. Remote Copy and Peak Find operations are also available. This option also contains 6 isolated relay outputs corresponding to the 6 Table Mode limit set points. Relay outputs for system status and relay status are also provided.

The electronics consists of the following: 10 optical isolators that provide the input interface. These isolators require an ac or dc voltage between 6 and 40V RMS to operate. An on-card power supply consisting of Q2 and Q3 provides a ground referenced 10V power source if needed. The isolators are read by input ports Z11 and Z12. Eight individual relays K1 through K8 provide the output information and are controlled by relay driver Z6 and output port Z5. Z18, Z19, and Z20 provide Data and Address Bus buffering. Chip Select Decoding is provided by Z17 and Z21. Bus direction control is provided by Z3 and Z4.

Figure 5.27 I/O Relay Diagram

This section is designed to help you recognize and isolate the causes of operational problems that could occur with your Quadrex 200.

In this section you will find a list of symptoms, with the corresponding instrument sections to be checked for possible failure.

These checks should make it possible to solve most problems by replacing P.C. boards or assemblies; this outline is not intended to be a component level solution. Qualified service personnel may refer to Chapter 5 - Electronic Circuitry - for more detailed descriptions and schematic drawings.

WARNING: HIGH VOLTAGE exists in the cables, Operator's Console, and the Sensor Control Unit. Extreme care should be exercised when operating the unit with covers removed.

Following is a brief outline of information in this section:

SYMPTOM CHECK LIST

USING THE TEST MODE

INTERCHANGING THE SENSORS

SERVICING AND CLEANING THE SENSORS

Symptom Checklist	Check
No CRT raster, power pilot LED off.	Fuse Linecord Power Supply [017-380]
No CRT raster, power pilot LED on.	Brightness potentiometer 12 volt Power Supply [017-380] Video Generator [017-320]
CRT raster only, no video data.	Video generator [017-320]
Video version message appears, but no MENU follows.	Central Processing Unit (CPU) card [017-330]
"AC DISTURBANCE" message only.	Power supply [017-380/Z2 & Q3] Line voltage
No keyboard response.	CPU card [017-330/Z2 & Z30] Front panel connector Keyboard
"PROGRAM LOSS" message always appears.	Power supply [017-380/Z7 & Q3] CPU card [017-330/Z8 & Z9] Battery [B1] on CPU card [017-330]
"CABLE ERROR" message always appears.	Sensor Control Unit (SCU) cable Measurement Control card [901-312] Bias Regulator card [901-322]
"EMISSION ERROR" message always appears.	Insufficient vacuum Sensor Bias Cable Bias Regulator card [901-322] Power supply [017-380] Sensor Filament (should not be open) Ion Source may be shorted Measurement Control card [901-312]
"RF ERROR" message always appears.	Sensor RF cable RF/dc card [901-302] Power supply [017-380] Measurement Control card [901-312] Sensor

No spectra	Test mode should be OFF Sensor output cable Emission should be ON Degas should be OFF If you have a Faraday Cup (FC) Sensor with an Electron Multiplier (EM) power supply, the EM voltage should be OFF. If you have an EM Sensor the EM voltage power supply should be ON. SCU cable Measurement Control card [901-312] Preamplifier card [017-390] Make sure the SCU is tuned for the sensor The sensor may be contaminated EM may be defective Pressure may be too low for FC
No TEST mode spectra	Make sure the unit is in TEST mode GAIN may be set too low Preamp card [017-390] Measurement Control card [901-312]
Poor sensitivity	Sensor maybe contaminated System pressure may be too low SCU cable Preamp card [017-390] Measurement Control card [901-312] Sensor tuning SCU May be in an excessive magnetic field
Poor peak shapes	Sensor may be contaminated System pressure may be too high RF/DC card [901-302] Sensor tuning SCU
High noise level	System grounding Sensor output cable Preamp card [017-390] EM may be defective

USING THE TEST MODE

The MENU display allows you to operate the Quadrex 200 in Test Mode as an aid in troubleshooting. When you select the Test Mode operation (key 6), an artificially derived signal is injected into the amplifier in place of the sensor output.

INTERCHANGING SENSORS

Because of the critical tolerances in quadrupole structures, no two sensors have exactly the same operating characteristics. The Quadrex 200 SCU is designed so that it can be adjusted (as described in Section 3) to match any individual sensor. If you plug in a different sensor, the peak widths and locations will not normally be exactly correct, unless you re-adjust your SCU.

SERVICING AND CLEANING THE SENSORS

The performance of a quadrupole sensor is significantly affected by contamination of critical electrode surfaces in the ion source, analyzer, and electron multiplier sections. Sensors normally require cleaning after a period of use; the length of time before cleaning is required varies widely with the conditions of use.

Light contamination can often be removed by baking the head in high vacuum. For more thorough cleaning the head must be disassembled. Since re-assembly requires careful alignment, contact the Inficon Service Department if you believe that major cleaning is necessary.

CAUTION: DO NOT attempt to clean the head (with solvents) without disassembling.

This Section describes the options which can be included in the Quadrex 200 to provide special capabilities. The Quadrex 200 has spaces to accommodate 2 option boards simultaneously. In this section you will find the following topics:

INSTALLING THE OPTION BOARDS

DESCRIPTIONS
- Relay Output Module
- Analog Output Module
- I/O Relay Module
- IEEE-488 Communications/Plotter Option
- XY Digital Plotter

The following options are also available. If ordered, instructions will be shipped separately.

SENSOR HEATING JACKET

IPC-1 PRESSURE CONVERTER

INSTALLING THE OPTION BOARDS

WARNING: High voltages are present inside this unit when power is applied. DO NOT open the cover unless the power cord is removed from the rear of the unit.

NEVER OPERATE WITH THE COVER OFF!

1. Remove the two screws in the upper corners of the rear panel so that the top of the control unit can be removed by sliding it to the rear. Take the top completely off. (See Figure 7.1).

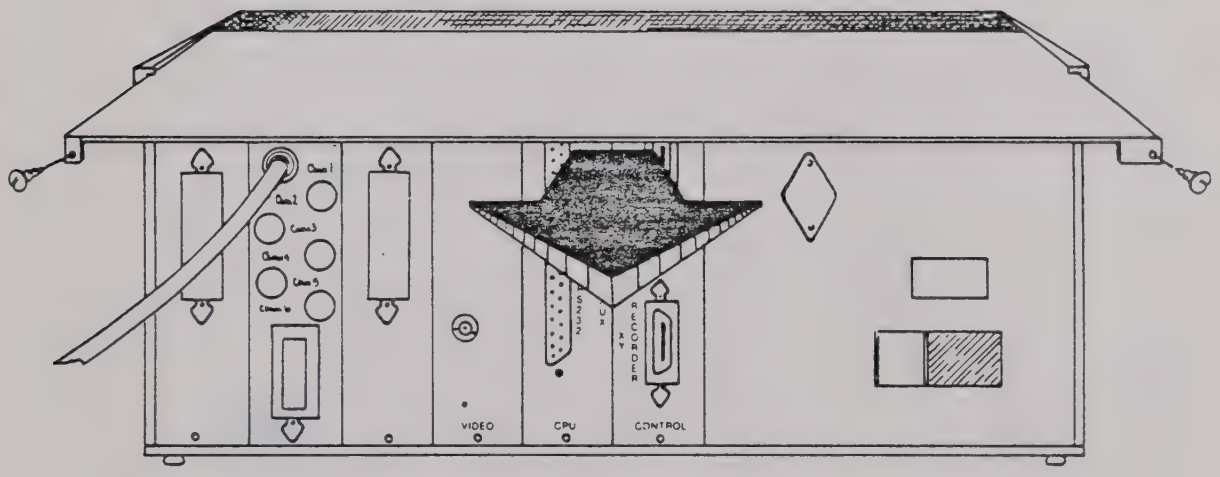


Figure 7.1 Operator's Console Cover

2. Option cards can occupy any of the two locations in the left half of the rear panel (as viewed from the rear). Remove the cover plate from the desired slots. Then carefully insert the card as shown in Figure 7.2, noting that there are alignment slots to insure the correct mating of the board and sockets. Make sure the board is fully inserted in the sockets. Install the 3 screws in the rear panel and replace the cover.

WARNING: Reinstall the cover before applying power to the unit.

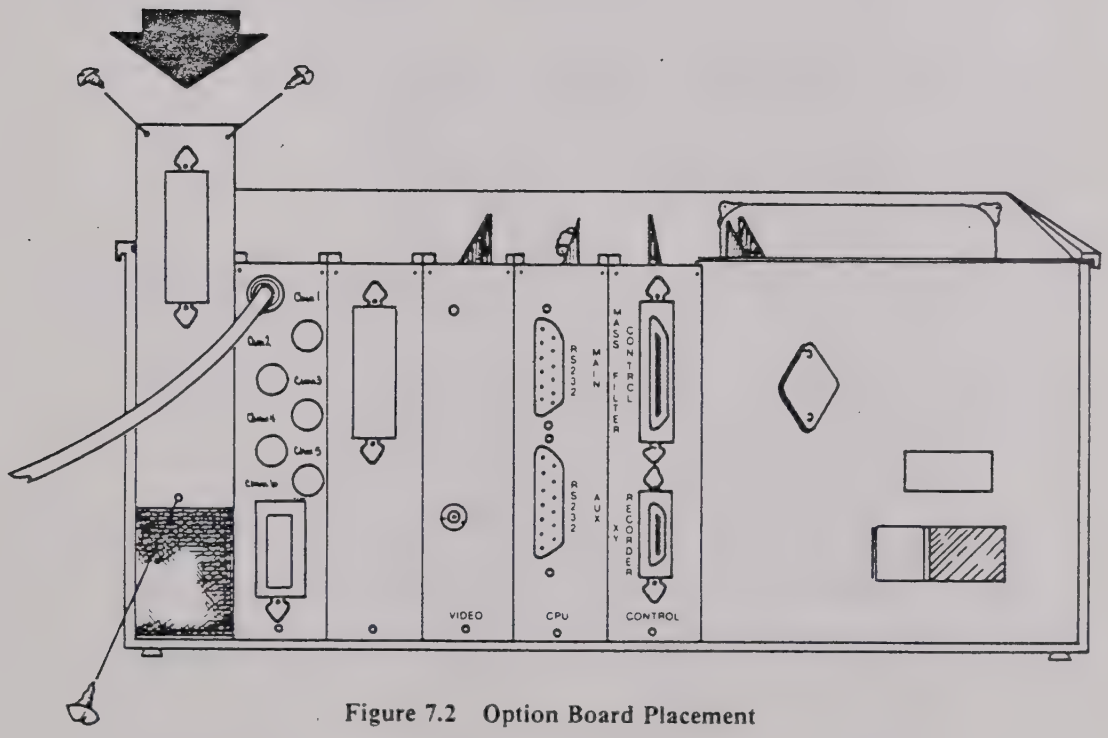


Figure 7.2 Option Board Placement

RELAY OUTPUT MODULE

With the Relay Output Module (option board) you can use the TABLE display to control external events (such as alarms, valves, etc.). There are 8 relays on the board; each relay provides a pair of isolated contacts which are accessible through the rear connector. The relays perform the following functions:

Relays 1-6 (Channel Limits) - Each relay number has a corresponding channel number. If the relays are activated (via the front panel switch), the contacts close when the VALUE measured in a specific channel exceeds the LIMIT which was programmed for that channel.

Relay 7 (Relay Status) - The contacts close when instrument conditions permit relays to be active.

Conditions: When the instrument is configured for interleaving or currently operating in TABLE display mode

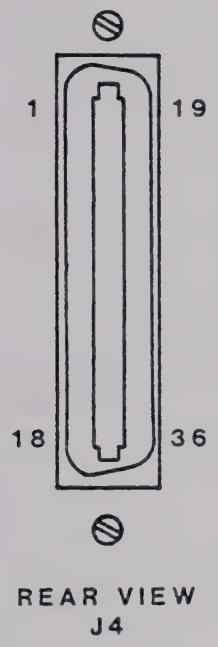
The relays are activated with the front panel push button.

Relay 8 (Instrument Status) - Closed when instrument conditions are valid for making measurements.

Conditions:
Emission On
Electron Multiplier On (if configured for EM)
Degas Off
Test Off

Maximum Contact Ratings, all relays:

120V rms (to terminal of same relay or to chassis)
100VA
1 amp



CONNECTOR CONTACT DEFINITIONS

RELAY#	CONTACT	FUNCTION
1	9, 27	CHAN. 1 LIMIT
2	10, 28	CHAN. 2 LIMIT
3	8, 26	CHAN. 3 LIMIT
4	11, 29	CHAN. 4 LIMIT
5	7, 25	CHAN. 5 LIMIT
6	12, 30	CHAN. 6. LIMIT
7	6, 24	RELAY STATUS
8	13, 31	INSTRUMENT STATUS

Figure 7.3 Relay Option Output Connector

When the Quadrex 200 is initially turned on, the channel limit relays are inactive (contacts open) and the "RELAY" message flashes on the screen. Relay 7 contacts (Relay Status) will be open indicating limits disabled and Relay 8 contacts (Instrument Status) will be open indicating that operating conditions are not valid for data taking. The Relay button on the front panel is used to switch the channel limit relays between active and inactive states. Relay 7 provides an external indication of whether the limit relays are active or inactive. This control is included so that the channel limit relays do not begin to operate external devices until the proper operating conditions for the Quadrex have been established.

When the instrument is not ready to take valid data, (e.g., emission is off) Relay 8 contacts will be open. This relay is provided to warn that the Quadrex 200 is not providing valid control outputs. It should be noted that Relay 7 contacts may still be closed at this time if having been previously enabled by the front panel button.

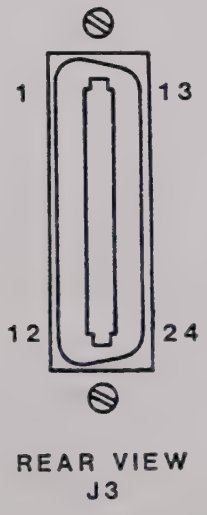
The operation of the channel limit relays is controlled only by the TABLE display program. If this program is changed while the relays are in use, the relays may not respond in the intended manner. When the TABLE display is running, the data for the channels are measured sequentially and the channel limit relays are updated one at a time. The relays remain in this state until the next measurement and update occurs. The frequency of updating depends on the gain and scan rate of all the channels.

Interleaving allows the use of the instrument in other display modes without losing the operation of the channel limit relays. At the end of each scan in another mode, the instrument will revert internally to the Table program and update the relays. The frequency of updates depends on the time consumed by one scan in the other mode. See Section 3 for details.

ANALOG OUTPUT MODULE

The Analog Output Module provides output voltages corresponding to measurement data developed by the Quadrex 200. These voltages may be used for external recording or control purposes. There are 8 voltage outputs available on the rear panel. The function of these voltages is as follows:

Channels 1-6	The output voltage (in volts) is equal to ½ of the VALUE shown in the corresponding channel of the TABLE display. (A value of 10.0 results in 5 volts out).
Channel Y	The output voltage (in volts) is equal to ½ of the vertical scale amplitude of the current reading in the active display mode. (A reading of 10.0 results in 5 volts out.) This is a real-time output.
Channel X	The output voltage (in volts) is equal to 1/10 of the mass number in the current display. (100 amu results in 10 volts out.) This is a real-time output.



CONNECTOR CONTACT DEFINITIONS

CONTACT	FUNCTION
3	CHAN. 1
7	CHAN. 2
4	CHAN. 3
8	CHAN. 4
5	CHAN. 5
9	CHAN. 6
6	Y DATA
10	X DATA
13 → 24	GND.REF.

OUTPUT IMPEDANCE: 500 OHMS

Figure 7.4 Analog Option Output Connector

I/O RELAY MODULE

The I/O RELAY option module provides the ability to remotely activate the Quadrex 200 front panel control functions. This gives a user the ability to use a Quadrex 200 in conjunction with a hardware interface in a hands-off mode of operation. The user is provided with optically isolated inputs, each having a direct command function. The inputs are operated with either AC or DC voltage within the range 8 to 40 volts RMS. Most control functions have separate input lines for turn ON and turn OFF operations. The following list gives the available controls:

1. EMISSION ON
2. EMISSION OFF
3. DEGAS ON
4. DEGAS OFF
5. ELEC MULT ON
6. ELEC MULT OFF
7. RELAY ON
8. RELAY OFF
9. COPY
10. PEAK FIND

(see Fig. 7.5 for related pin connections)

If both inputs occur simultaneously, the OFF command has priority. If pulsed input commands are used, the pulse duration must be greater than .3 seconds. All inputs are leading edge detected and therefore may remain active until their function is again desired; they then must be turned off for a minimum of .3 seconds before being reactivated. All input lines share a common isolated reference input. This line is normally connected to the common side of the users "CONTROL" power supply. If no external power source is available, a 10 volt DC power source is provided at the I/O RELAY module input connector J2. This power sources should only be used to operate the input isolaters on the I/O RELAY module, and not as a power source for any other system needs. The common reference input line must be connected to GROUND if the internal power source is to be used. The contact closures used to activate the remote input lines are normally resident in the user's electronics system; however, for some applications the contacts may be the LIMIT and STATUS relay outputs provided by the Quadrex 200 itself. A schematic is shown in Figure 7.6 for both types of remote input supply wiring.

INPUT LINE SPECIFICATIONS:

OPERATING RANGE:	8 to 40 Volts AC (RMS) or DC
REFERENCE:	Common input line
ISOLATION:	1 KV Maximum
INPUT IMPEDANCE:	820 Ohms
INPUT THRESHOLD:	3 Volts

ON CARD POWER SOURCE SPECIFICATION:

OUTPUT VOLTAGE:	10 Volts DC
OUTPUT CURRENT:	120 mA Max.
REFERENCE:	Chassis Ground

The I/O RELAY option module also provides 12 sets of isolated relay contacts with the same functions as the RELAY option module. The two options may be installed at the same time giving a user parallel output functions with isolated contacts. The I/O RELAY option contact ratings are reduced from the ratings of the standard RELAY option card. The new rating is 40 volts max. at a 40 va max. A description of the RELAY functions follow:

RELAY 1-6 (Channel Limits)

Each relay number has a corresponding channel number. If the relays are activated (via the front panel switch or remotely), the contacts close when the value measured in a specific channel goes outside the limits which were programmed for that channel.

RELAY 7 (Relay Status)

The relay contacts close when the relays have been activated by the front panel button or a remote command.

RELAY 8 (Instrument Status)

The relay contacts close when all instrument conditions are met for making valid data measurements.

Conditions:	Emission On
	Electron Multiplier ON (If EM version)
	Degas Off
	Test Off

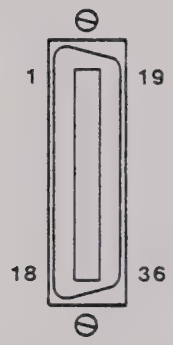
When the Quadrex 200 is initially turned on all relay contacts will be in the inactive state (normally open) and will remain there until their operating conditions are met.

MAXIMUM RELAY CONTACT RATINGS:

VOLTAGE:	40 Volts RMS
CURRENT:	1 Amp
POWER:	40 VA
ISOLATION:	250 Volts

There are several Input lines and Output relays that are present at the connectors but do not as yet have defined functions. This hardware should be ignored at the present time.

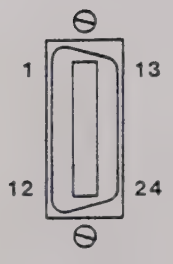
I/O RELAY OPTION - CONNECTOR DESIGNATIONS



REAR VIEW
J1

RELAY OUTPUTS J1

CONTACTS	FUNCTION
9,27	CHANNEL 1 LIMIT
10,28	CHANNEL 2 LIMIT
8,26	CHANNEL 3 LIMIT
11,29	CHANNEL 4 LIMIT
7,25	CHANNEL 5 LIMIT
12,30	CHANNEL 6 LIMIT
6,24	RELAY STATUS
13,31	INSTRUMENT STATUS
4,22	PPC STATUS
5,23	UNUSED
15,32	UNUSED
14,33	UNUSED

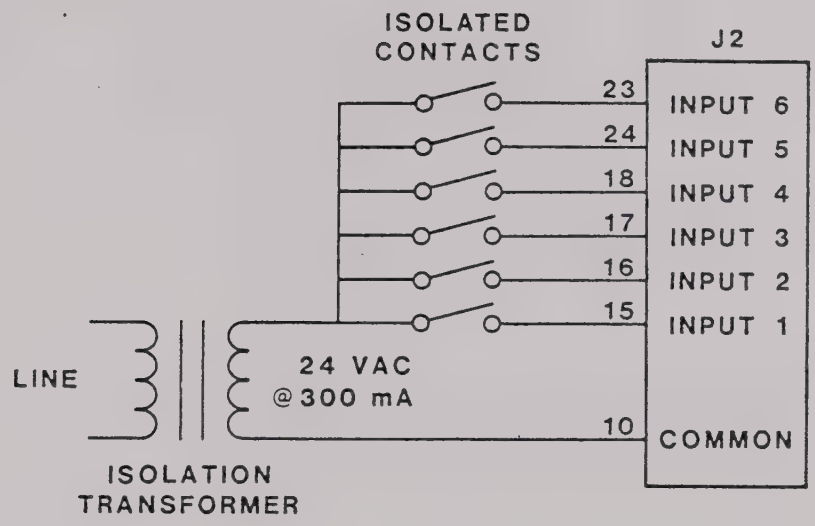


REAR VIEW
J2

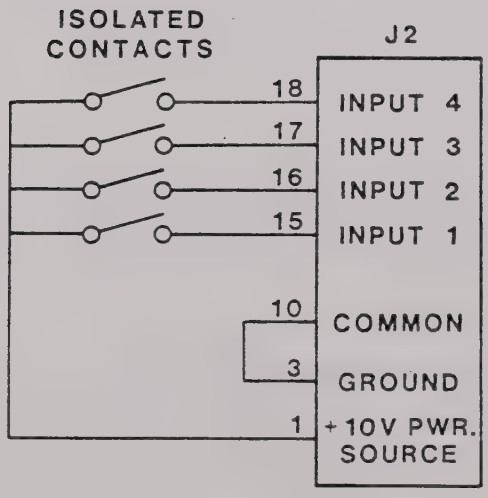
REMOTE INPUTS J2

CONTACT	FUNCTION
17	EMISSION ON
15	EMISSION OFF
16	DEGASS ON
18	DEGASS OFF
19	EMULT ON
20	EMULT OFF
13	RELAY ON
14	RELAY OFF
24	COPY
23	PEAK FIND
10	INPUTS COMMON
3,4,5,6	GROUND
1	+10 VOLT SOURCE
22	FLOW ON PPC -
21	FLOW OFF PPC -

Figure 7.5 I/O Relay Option Connector Designations



1. External Power Supply



2. Internal Power Supply

Figure 7.6 Typical Remote Input Wiring Techniques

IEEE-488 COMMUNICATIONS/PLOTTER OPTION

The IEEE 488 Interface provides the capability for a variety of devices to communicate with each other and to share the resources of the system. This means the entire system can share one printer or one computer instead of each instrument having a computer and printer dedicated specifically for it's use alone. To implement the IEEE-488 interface in a Quadrex 200 an optional plug-in board is available.

CAUTION: For proper operation of the IEEE-488 interface, the PCB must be inserted into the Quadrex 200 with no empty slots between it and the video board.

Option and Address Switch

An eight segment switch is located on the rear panel of the 488 option board. This sets the 488 bus address for the Quadrex 200 and selects the type of communications (serial or 488) for the remote computer and the graphics plotter. Follow the three steps below when determining the types of communications required:

STEP 1

Setting switch #8 to 1 selects 488 communications to the computer. If 488 is selected go to Step 2, below. Setting the switch to a Ø selects serial communications through the standard RS-232 interface connector, RS-232 MAIN is selected even though the IEEE option board may still be installed in the Quadrex 200. If serial communication is selected, go to step (3b) below.

STEP 2

Once the 488 communications has been selected, the proper IEEE device address must be set using switches #1 through #5. Continue to step (3a). The user may select any address from Ø-3Ø. The address is preset to 3.

STEP 3

Switches #6 and #7 are used to determine whether communication to the graphics plotter is to be serial or 488.

STEP 3a

Setting switch #7 to 1 sets up the Quadrex 200 for 488 communications with the plotter in the addressed talker/listener mode (TON). Switch 7 is only used if switch #8, mentioned above, is set to 1 for 488 communica-

tions with the computer. Setting switch #7 to Ø directs plotter communication through the auxiliary serial port; set to 1, communication is through the 488 bus.

When switch #7 is set to 1, the copy event works differently than if serial or 488 (TON) were selected, since in this mode the graphical information is not immediately sent to the plotter. This is because the Quadrex 200 must first be addressed to talk and the plotter addressed to listen by a Host.

In this configuration then, there must be a computer connected to the bus that has 488 Host capability. When the Quadrex 200 COPY button is pressed, the Host computer is informed that the Quadrex 200 has a copy request and wants to communicate with the plotter. This is accomplished by the Quadrex 200 via the service request line on the 488 bus. The Host then detects the request for service and serial polls all the devices on the bus until the device that requested service is found.

When Quadrex 200 is serial polled by the Host, it sends the Host a hexidecimal 21 indicating that it has had a COPY key event and wants to be addressed to talk to the plotter. The Host accomplishes this by first sending the 'B8' command to Quadrex 200 which, in turn, activates the code necessary to transmit data to the plotter. At this point the Quadrex 200 will not transmit any data because it has not been addressed to talk. The Host must now send an unlisten to any active listeners on the bus. Next, the Host addresses the plotter by asserting the service request and sending the hexidecimal 22. This sequence of events is dependent upon the Host since it can respond to the service request or send the start up message at any time. Disregard step (3b) if 488 communications have been selected.

STEP 3b

Setting switch #6 to 1 sets up the Quadrex 200 for 488 communications to a talker only mode (TON). In the TON mode the Quadrex 200 can never receive data from a computer through the 488 bus and the device address switches have no meaning. The Quadrex 200 still has the capability of communication with a computer through the main serial port. Note that in the TON mode the graphics plotter must be set in the listen only mode. This configuration should only be used when the Quadrex 200 is connected to a dedicated plotter. If the plotter does not receive the data, the communications will time out in approximately fifteen seconds and the COPY message will be erased from the screen.

Summary of Switch Definitions

For switches 1 through 8 the following DATA Levels apply:

1 = Logic High, Ø = Logic Low, X = unimportant (1 and / refer to panel markings, not switch markings.)

Switch #1-5 DATA Levels for Device Addresses

Switch number	Value if DATA = 1	Value if DATA = Ø
1	1	Ø
2	2	Ø
3	4	Ø
4	8	Ø
5	16	Ø

Switch #6-8 DATA Levels

Switch number	#6	#7	#8
Serial Communications	X	X	Ø
488 Communications	Ø	X	1
Serial Plotter	Ø	Ø	X
488 Plotter (T/L)	Ø	1	1
488 Plotter (TON)	1	X	X

Unused 488 Commands in the Quadrex 200

The following 488 commands have not been implemented in the Quadrex 200:

Local Lockout
Remote Enable
Device Trigger
Secondary Address

COMMUNICATING WITH THE QUADREX 200

The Quadrex 200 is a talker/listener device on the 488 bus under the control of a computer acting as a Host. The Quadrex 200 can receive and interpret only one command at a time. Each command sent by the Host to the Quadrex 200 must have an ASCII carriage return and line feed characters added on to the end of the command as End of Identity (EOI) characters. All data returned from the Quadrex 200 to the Host will also have the same EOI characters added to the end of the data. By not completing the three wire handshake upon receiving the EOI characters the

Quadrex 200 holds off the command by command transfer. The handshake is completed when the command is completed. At this point the Host can send the next command.

To send a command to the Quadrex 200 the Host must send an unlisten to all devices on the bus. This will disable all devices to receive data. The Host must then address the Quadrex 200 to listen and then send the command. At this point the Host must decide whether the command just sent will result in data being returned to the Host. If data is to be returned, the Host must tell the Quadrex 200 to be a talker and set itself up as a listener. The data is terminated by the EOI characters and the EOI line is also asserted, which completes the command.

If a command is sent to the Quadrex 200 (that puts data to the transmit buffer) and then another command is sent without transmission of the data in the transmit buffer, the Host will receive an error message. Since data stacks up in the transmit buffer it may be necessary to send as many as 3 DEVICE CLEAR commands to clear the transmit buffer.

Device Clear

May be initiated by the Host and sent to the Quadrex 200. When this signal is received by the Quadrex 200 the receive and transmit buffers will be cleared. This command may be repeated up to 3 times since the transmit buffer holds 100 bytes and the maximum transfer of data is 300 bytes.

SERVICE REQUEST AND ERRORS

The Host must at all times monitor the service request line. This line is asserted by the Quadrex 200 to tell the Host that there is a communication error, the command just transmitted is in error, or to request service from the Host for a reason other than error status. The device that requested the service is indicated to the Host if bit D6 is set to 1 in the data byte of the device port polled. The error codes below do not include this "flag" bit (Value = 64D).

No Error Value	Command Error Condition
0001	Illegal command
0002	Illegal data
0003	Illegal begin and/or end index for either the current mode or for the command.
0004	Illegal select mode pointer (1..4 are valid)
0005	Illegal display mode on the Quadrex 200 screen for the attempted event.
0006	Illegal count for a particular escape sequence.

No Error Value	Command Error Condition (cont'd)
0007	Illegal programmable parameter
0008	Invalid stored parameter number (BAR-SUBTRACT parameters).
0009	Pressure not displayed due to emission off or degas on.
0010	Invalid relay command.
0011	Copy requested when copy is already running.
0012	Degas requested when emission is off.
0013	Electron multiplier requested when not in unit or emission is off.

Communication Errors

81H=129D - Illegal termination as a listener. This indicates that the Quadrex 200 was addressed to listen but was then sent an unlisten without the EOI characters being received. This reinitializes the transmit and receive buffers. The command is not executed.

82H=130D - This indicates that the Quadrex 200 was addressed to talk but was then sent an untalk with data still in the buffer. This leaves the transmit buffer data intact. The Host has the option of addressing the Quadrex 200 to receive the data, or to send a DEVICE CLEAR which reinitializes the transmit and receive buffers.

83H=131D - Receive buffer overflow. This indicates that the command being sent to the Quadrex 200 is larger than the receive buffer allows. This reinitializes the transmit and receive buffers.

84H=132D - Addressed to listen but data is still in the transmit buffer. This indicates that the previous command sent by the Host had data sent to the transmit buffer, but the Host never addressed the Quadrex 200 to talk before transmitting the next command. This leaves the transmit buffer data intact. The Host has the option of addressing the Quadrex 200 to talk and transfer the data, or to send a DEVICE CLEAR to reinitialize the transmit and receive buffers.

Other Service Request Commands

21H=33D - The Quadrex 200 has received a copy request from the front panel COPY button or a copy request command has been received. This indicates to the Host that the Quadrex 200 wants to communicate to the graphics plotter. This can occur at any time.

22H=34D - The Quadrex 200 has completed it's communication with the graphics plotter, the Host can resume transmission of commands to any device on the bus.

IEEE BUS INTRODUCTION

The IEEE 488 utilizes a party line bus structure to which a maximum of 15 devices may be connected in one contiguous bus. The 488 Bus transfers data in a byte serial, bit parallel manner among the devices. Included on the bus are 8 bi-directional data lines, 8 command lines, and 8 ground lines. Data is transmitted only after a three wire handshake has been completed, thus preventing data loss. Every device on the bus must be capable of being a talker, listener, or a Host.

Data Lines

There are 8 bi-directional data lines on the 488 bus which are used to transfer information from device to device. Normally, the data is ASCII formatted with the MSB used for parity if desired. Information transferred includes interface commands, addresses, and device dependent data.

Handshake Lines

There are three lines which are used to coordinate data transfer over the bus from a source to the acceptor of the data. This technique has the following advantages:

Information transferred is asynchronous and adjusted to the speed of the sender and receivers and therefore runs at the rate of the slowest addressed device.

More than one device can accept data at the same time.

Every byte transferred goes through the handshake.

The three handshake lines use a low true logic convention to implement the wired or of the NRFD and NDAC lines, provide active true-state assertion, and reduce noise susceptibility in the true state.

Three Handshake Lines

DAV - Data valid, controlled by the source
NRFD - Not ready for data, controlled by the acceptor
NDAC - No data accepted, controlled by the acceptor

In a typical data exchange, all devices currently designated as active listeners would indicate when they are ready to receive data by setting NRFD false. A device not ready would set NRFD true. The talker will not sense NRFD false until all active listeners are ready for data and they have set NRFD false. When the talker senses NRFD false, it places a byte of data on the data bus and sets DAV true. This tells the listeners that

the data on the data bus is valid and it may be read. Each listener, at his own speed, reads the data and sets NDAC false indicating that it has read the data. When all the active listeners have set NDAC false, the talker starts the sequence over for the next byte of data.

Interface Management Lines

These 5 lines are used to manage the flow of information across the interface:

ATN = attention, all devices must monitor the ATN line at all times and respond within 200NS. When this line is true, the interface is placed in the 'Command Mode' where all data is interpreted as commands. When this line is false, the interface is in the 'Data Mode' where all data is interpreted as device dependent data. Addresses are sent during the command mode.

IFC = interface clear, asserted by the system Host to halt current operations on the bus and bring the bus to an idle state. This includes unaddressing all talkers and listeners and disabling serial poll. All devices must monitor IFC at all times and respond with 100NS.

SRQ = service request, is used by a device to alert the Host for a need to communicate with it. The Host will then perform a serial poll to determine who requested the service and why. This represents a request, not a demand, and it is up to the Host to determine when and how it will service the device. The device will continue to assert the 'SRQ' line until it has been satisfied.

EOI = end of identify, when ATN is true the EOI line is used by the Host to conduct a parallel poll. When ATN is false, the EOI indicates the end of a multibyte data message from a talker.

Data Mode

In the data mode, device dependent data is sent from the active talker to the active listeners on the bus.

Command Mode

The command mode has several different purposes:

Talk or Listen Devices - Select the instruments that will send or accept data.

Universal commands - Cause every instrument to perform a specific operation if it is capable.

Addressed Commands - Similar to universal commands except that they affect only those instruments that are addressed.

Secondary Commands - Always used with an address, universal command, or addressed command to provide additional command codes.

Addressing

Device addresses are used by the active Host in the command mode to specify who talks and who listens. The five least significant bits in the incoming data for the address are the actual address of the device on the interface. Bits 5 and 6 are used to distinguish between a device's talk and listen address. An ASCII '-' and '?' are used to tell every device to untalk or unlisten. Therefore, device address 31 is illegal and the maximum usable addresses are 0 - 30.

Universal Commands

UNT — The untalk command unaddresses the current talker. Sending an unused talk address would accomplish the same thing. This command is provided for convenience since addressing one talker automatically unaddresses the others.

UNL — The unlisten command unaddresses all active listeners on the bus. Since listeners cannot be unaddressed without unaddressing all listeners, it is necessary that this command be sent to guarantee that only the listeners desired are addressed.

UCL — The universal device clear command causes all devices capable of recognizing this command to go to a predetermined device dependent state. Devices respond whether they are addressed or not.

SPE — The serial poll enable command causes all talker devices on the interface to go to serial poll mode. When each device is addressed to talk, it will return one byte of data indicating it's status. A device must be capable of talking to respond to this command.

SPD — The serial poll disable command terminates serial poll and returns the devices to their normal talking state where they output device dependent data instead of status information.

Three other universal commands were discussed earlier. They were: ATN, IFC, and EOI; .

Addressed Commands

SDC — The selected device clear command is similar to the universal device clear command except only those devices that are currently listening will recognize this command.

PPC — The parallel poll configure command causes the addressed listener to configure according to the parallel poll secondary command.

Polling

There are two possible polling procedures available to a user. They are serial and parallel.

Serial poll enables a Host to determine which device or group of devices asserted the service request command line. Each device which can be serial polled (requires talker subset) will return one byte, indicating that it requested the serial poll and the status information or that it did not request the serial poll. Every device should be polled to ensure that every request device is satisfied. When the serial poll is completed, 'SPD' and 'UNT' must be sent to complete the serial poll sequence.

Parallel poll is a Host initiated operation to obtain information from the devices. When parallel poll is initiated, each device returns a status bit via one of the 8 data lines. Each device is assigned a data line either from switches or via the Host during a 'PPC'. Configured devices must respond within 200NS.

MESSAGE PROTOCOLS

General Format of All Valid Messages

All messages sent by the host are strings of ASCII characters, Carriage Return (CR), and Line Feed (LF).

In some descriptions of messages in this manual the slash character ('/') will be used for demonstration purposes to separate the different parts of the message. The slash ('/') should NOT be included in the actual messages to the Interface, as this will result in an error command.

The Quadrex 200 will not send a response for every command from the Host. ONLY COMMANDS REQUESTING DATA WILL INITIATE A RESPONSE.

The general format of a command message is:

```
Host Command:  Command Character  Contents of Commands...  CR  LF
Quadrex 200 Response:             Contents of Response...   CR  LF
```

QUADREX OPERATING PARAMETERS

These messages allow the host to point to any Quadrex 200 operating parameter values, to point to either actual or alternate data, and to either query the present value or command a change to be made in the value.

Normal Data Pointer

Host Command: N CR LF
Quadrex 200 Response: No Response

The currently measured (normal) Quadrex 200 data is selected, as opposed to the stored (alternate) data. All subsequent commands and queries concerning Quadrex 200 operating values and spectrum values will reference the current Quadrex 200 data. This normal data set is the default set pointed to on Quadrex 200 power-on.

The command messages affected by this command are: FETCH, GET, PARTIAL PRESSURE READ, and the STATUS command for HEAD STATUS, PRESSURE VALUE, or SCAN TIME.

Alternate Data Pointer

Host Command: A CR LF
Quadrex 200 Response: No Response

Sending this message identifies to the Interface that the alternate (stored) data are to be used for all subsequent queries. This is opposed to the Normal, or current Quadrex 200, data values (see Normal Data Pointer Command). The default data set referenced on power-on of the Quadrex 200 and the Interface is the Normal set of data.

The subsequent commands that are affected by this pointer command are: FETCH, GET, PARTIAL PRESSURE READ, and STATUS command for HEAD STATUS, PRESSURE VALUE, or SCAN TIME.

Display Mode Change

Host Command: M Display Character CR LF
Quadrex 200 Response: No Response

Any one of the eight unstored display modes may be commanded to appear on the Quadrex 200 crt screen.

To display a mode on the Quadrex 200 screen, MEM-X must not be on, and one of the following display characters must be given in this Display Mode Change command:

Quadrex Display Mode	Display Character
MENU	0
ANALOG	1
BAR-GRAPH/LIB	2
TABLE	3
LEAK CHECK	4
PARTIAL PRESSURE	5
BAR-SUBTRACT	6
USER LIBRARY	7
SPECTRA LIBRARY	8

Alternate (Stored) Mode Pointer

Host Command: D Display Character CR LF
Quadrex 200 Response: No Response

Any of the five stored displays may be chosen with this command message as the referenced display for subsequent data queries sent to Quadrex 200, by selecting one of the display characters listed below. This command refers strictly to the Alternate (stored) data set, and thus is not dependent on the data set pointed to previously. The only commands affected by this pointer are the GET command, and the STATUS command for PRESSURE VALUE, HEAD STATUS, or SCAN TIME.

ALTERNATE Display	Display Character
ANALOG	1
BAR-GRAPH/LIB	2
TABLE	3
LEAK CHECK	4
PARTIAL PRESSURE	5

Parameter Pointer

Host Command: P Parameter Character(s)... CR LF
Quadrex 200 Response: No Response

Any of the Quadrex 200 parameter values, normal or frozen, may be selected. Any subsequent FETCH or UPDATE command messages will depend on which parameter is pointed to by this command.

General Parameter Numbers

Display Mode	Gain	Scan	EM Voltage	Mass Center	Width
ANALOG	0	1	2	3	4
BAR-GRAPH/LIBRARY	5	6	7	8	9
TABLE	---	11	12	---	---
LEAK CHECK	43	44	45	46	---
PARTIAL PRESSURE	---	48	49	---	---
BAR-SUBTRACT	161	162	163	164	165
USER LIBRARY	---	---	---	---	---

General Display Parameter Numbers

Display Mode	LIB#	Volume	Pressure Unit	Pressure Sensitivity	Pressure Exponent
BAR-GRAPH/LIBRARY	10	---	---	---	---
LEAK CHECK	---	47	---	---	---
PARTIAL PRESSURE	---	---	50	51	52

TABLE Display Parameter Numbers

Parameter	Channel 1	Channel 2	Channel 3	Channel 4	Channel 5	Channel 6
GAIN	13	18	23	28	33	38
CALIBRATION	14	19	24	29	34	39
LOW LIMIT	15	20	25	30	35	40
HIGH LIMIT	16	21	26	31	36	41
MASS	17	22	27	32	37	42

PARTIAL PRESSURE Display Parameter Numbers

Channel	GAIN	MASS	FACTOR
1	53	54	55
2	56	57	58
3	59	60	61
4	62	63	64
5	65	66	67
6	68	69	70
7	71	72	73
8	74	75	76
9	77	78	79
10	80	81	82
11	83	84	85
12	86	87	88

USER LIBRARY Parameter Numbers

LIB#	MASS 1-6	% 1-6
1	89-94	101-106
2	95-100	107-112
3	113-118	125-130
4	119-124	131-136
5	137-142	149-154
6	143-148	155-160

UPDATE THE PARAMETER POINTER

Host Command: U Data Characters... CR LF
Quadrex 200 Response: CR LF

The Update command allows the host to send selected values to Quadrex 200 for any of the programmable parameters listed in the description of the Parameter Pointer command, except for the five BAR-SUBTRACT parameters (parameter numbers 161 through 165, and Partial Pressure Gain parameters for the first six masses). The value of the parameter currently pointed to is changed with this command.

All parameters, except those listed above, are programmable with this command. The data fields are as follows for each of the seven types of parameters:

ELECTRON MULTIPLIER VOLTAGE - The acceptable values for the electron multiplier data field range from 100 to 300 with increments of 1 unit, corresponding to the Quadrex 200 electron multiplier voltages of 1000 to 3000 volts.

The format for updating the electron multiplier voltage is:

U/three digit value/CR/LF

SCAN - A single digit equal to a 0, or 1, or 2, or 3, or 4 corresponding to the following speeds:

0 ... very slow
1 ... slow
2 ... normal
3 ... fast
4 ... very fast

The format for updating the scan is:

U/0/CR/LF , to change to very slow scan
U/2/CR/LF , to change to normal scan
U/4/CR/LF , to change to very fast scan

GAIN - ANALOG, BAR-GRAPH, and LEAK CHECK Modes

The gain data field for all programmable Quadrex 200 displays other than TABLE is a three digit value, where the first digit is the gain multiplier, and the second and third digits are the negative exponents of 10 of the gain value.

The following data fields are valid for changing the gain in any display mode except for the TABLE mode:

Quadrex Display Scale	Data Field in Command Message
0...6, $1x10^{-7}$ amps	307
0...18, $1x10^{-8}$ amps	108
0...6, $1x10^{-8}$ amps	308
0...18, $1x10^{-9}$ amps	109
0...6, $1x10^{-9}$ amps	309
0...18, $1x10^{-10}$ amps	110
0...6, $1x10^{-10}$ amps	310
0...18, $1x10^{-11}$ amps	111
0...6, $1x10^{-11}$ amps	311
0...18, $1x10^{-12}$ amps	112
0...6, $1x10^{-12}$ amps	312
0...18, $1x10^{-13}$ amps	113

The format for updating the amps value of Quadrex 200 in all programmable display modes other than TABLE mode is:

U/three digit value/CR/LF

TABLE Display Mode Only

For updating the amps value of Quadrex 200 in the TABLE mode, a two-digit number comprises the data field. All table mode gains are $1x10^{-nn}$, where the factor nn is a value 08 through 13. Therefore the format for updating the amps in table mode is:

U/two digit value/CR/LF

- CALIBRATION FACTOR - A one or two digit value. The decimal point is not included in the data field, but is assumed to be located between the two digits given. So, the calibration data field ranges from 1 to 99 (inclusive) corresponding to the Quadrex 200 calibration factors from 0.1 to 9.9.

The format for updating the calibration value of Quadrex 200 in TABLE mode is:

U/one or two digit value/CR/LF

LOW LIMIT - All Low Limit values must be less than or equal to High Limit values.

HIGH LIMIT - All High Limit values must be greater than or equal to Low Limit values.

For LOW LIMIT and HIGH LIMIT - A three digit value, where a decimal point is assumed to be positioned between the second and the third digits, but is not included in the data field. Valid data fields for limit vary from 000 to 100 with increments of 1 unit, corresponding to Quadrex 200 limit values varying between 00.0 and 10.0.

The format for updating the limit value of the Quadrex 200 in TABLE mode is:

U/three digit value/CR/LF

CENTER MASS - For the ANALOG and BAR-GRAPH/LIBRARY measurement display modes, this is a 2-digit value ranging from 5 to 195 with increments of 1 amu.

The format for updating the center mass value in ANALOG and BAR-GRAPH/LIBRARY mode is:

U/one, two, or three digit value/CR LF

MASS NUMBER - A value ranging from 0 to 200 with increments of 1 amu, valid in the TABLE and LEAK CHECK display, the last six masses of the PARTIAL PRESSURE display, and the USER LIBRARY display.

The format for updating the mass number in TABLE mode is:

U/one, two, or three digit value/CR/LF

PRESSURE UNIT - A one-digit value of 1, 2, or 3 corresponding to Torr, Mbar, or Pascal, respectively.

The format for changing the pressure unit is:

U/one digit value/CR/LF

SENSITIVITY MANTISSA - A three-digit value in the 9-999 range with an implied decimal point of XX.X.

The format for updating the sensitivity mantissa is:

U/three digit value/CR/LF

SENSITIVITY EXPONENT - A one-digit value in the 0-9 range corresponding to 10^{-0} through 10^{-9}, respectively.

The format for updating the sensitivity exponent is:

U/one digit value/CR/LF

FACTOR - A four-digit value in the 1 through 9999 range with an implied decimal point of X.XXX.

The format for changing the factor is:

U/four digit value/CR/LF

LIB# - A two-digit value in the 0 through 40 range corresponding to the fragmentation pattern.

The format for changing the LIB # is:

U/two digit value/CR/LF

WIDTH - A one-digit value in the 0 through 6 range corresdponding to a width of 10, 20, 40, 50, 100, or 200, respectively.

The format for changing the width is:

U/one digit value/CR/LF

VOLUME - A one-digit value in the 0 through 3 range corresponding to OFF, LOW, MEDIUM, and LOUD, respectively.

The format for changing the volume is:

U/one digit value/CR/LF

NOTE: None of the BAR-SUBTRACT mode parameters are programmable, as well as the six masses and twelve GAINS in the PARTIAL PRESSURE Display

This UPDATE command always references the Normal, or current, set of displays. The parameter values in the Alternate (stored) set of displays can not be programmed.

Fetch Parameter Pointer

Host Command: F CR LF
Quadrex 200 Response: 4 digit Quadrex 200 Parameter Value CR LF

A query is sent to Quadrex 200 for the value of the parameter pointed to by the Parameter Pointer Command. The parameter value transmitted to the host will be either a 1, 2, 3, or 4 digit value with preceding zeros so that all responses are four digits.

Type of Parameter Pointer to	Range of Response (excluding preceding zeros)
Electron Multiplier Voltage	100...300
Scan Speed	0, 1, 2, 3, 4
Amps (Quadrex 200 Table)	108...113
Amps (Quadrex 200 non-table and Partial Pressure displays)	307...113
Calibration	1...99
Limits	0...100
Center Mass	5...195
Mass Number	0...200
Pressure Unit	1, 2, 3
Sensitivity Mantissa	1...999
Sensitivity Exponent	0...9
Factor	1...9999
Volume	0...3
LIB#	0...40
Width	0...6

The parameter values returned to the host after this command (excluding any preceding zeros) are the same as the acceptable values which may be sent by the host in the UPDATE command with the exception of Table amps.

The response to this command depends on the data set pointed to by either the NORMAL DATA POINTER or ALTERNATE DATA POINTER; and it depends on the parameter previously selected by the PARAMETER POINTER command.

READING QUADREX 200 DATA

There are two basic ways the spectrum data acquired by the Quadrex 200 may be obtained by the host via the RS-232 Interface. The data may be read after it has been updated, as the sweep scans through the programmed mass numbers; or it may be read as it currently exists in the Quadrex 200 memory.

Data is transferred in blocks, which are defined by the INDEX command.

INDEX POINTER COMMAND

```
Host Command:        I   1st index value...   delimiter   2nd index value...   CR   LF
Quadrex 200 Response:        No Response
```

In commands whose response depend on this command are the GET, TAKE, and PARTIAL PRESSURE READ commands. In all measurement modes, this command is used by the HOST to select the range of data points or channel numbers. In TABLE mode, the command may be used to choose the range of channel numbers whose amplitude values are to be sent; the index values are single digits ranging from 0 to 5 corresponding to channel numbers from 1 to 6 for amplitude data sent with the GET or TAKE commands. In Analog and Leak Check Modes, the command is used to reference a data point range within the 201 data points in each scan; the index values are each between 0 and 200. In any case, the first index given is less than or equal to the second index given. In the Partial Pressure mode, the command is used to reference the channels 0 through 11.

The delimiter sent between the two mass numbers in the data field is simply any non-numeric character (except for the TRM, STX, CNL, and ESC characters), to separate the two values.

On Quadrex 200 power-on, the default values for the mass number indices of this pointer command are 0,0. This is a valid pair of mass number indices for any of the display modes and points to a single data point in each case.

GET INDEXED DATA ARRAY

```
Host Command:        G   CR   LF
Quadrex 200 Response:     amplitude of 1st index value,
                    ...,    amplitude of last index value    CR   LF
```

Either the NORMAL (last measured) or the ALTERNATE (stored) data of Quadrex 200 for the indexed (INDEX command) mass numbers is transferred to the host. When ALTERNATE is pointed to then the Alternate Mode Pointer determines what frozen data is to be transmitted.

The data is sent to the host in the form of: amplitude value of the first channel number, or data point number in the index command, amplitude value of the second data point, and so on until the amplitude value of the last data point or channel number, in the index command is sent, followed by the Eot character.

The amplitude values are transmitted as three-digit values, where a decimal point is implied, but not transmitted, between the second and third digits. For example, a response for a single indexed mass number of 060 corresponds to a peak value of 6.0 (x amps value). There are NO separators sent between the three-digit values, so the data sent will appear as a continuous sequence of digits.

NOTE: This command reads the raw data which is used to calculate the Partial Pressure in the Partial Pressure measurement mode.

TAKE INDEXED ARRAY, SYNCHRONIZED WITH SWEEP

Host Command: T CR LF
Quadrex 200 Response: amplitude of 1s index value,
..., amplitude of last index value CR LF

The real-time amplitude values for each data point or channel included in the INDEX Pointer command are transmitted to the host in this manner: once the Quadrex 200 receives this command from the host, and the scan of the Quadrex 200 returns to the first data point or channel in the current measurement mode, then one entire scan of amplitude values is transmitted to the Interface instead of to the Quadrex 200 screen, and the host receives an indexed set of amplitude values at the time at which Quadrex 200 is reading the amplitude value for each mass number, for those indexed values last selected with the INDEX command.

The amplitude values are transmitted in the form of three digit values, where a decimal point is implied between the second and third digits but is not sent. for example, a single transmission of 200 corresponds to an amplitude value of 10.0 (x amps value). There are NO separators sent between each three-digit value, so the data sent will appear as a continuous sequence of digits.

This command does not depend on the data set currently pointed to by the last ALTERNATE or NORMAL command: it always queries the NORMAL data set.

NOTE: This command gets the raw data when used in the Partial Pressure mode.

Miscellaneous Messages

PARTIAL PRESSURE READ

```
Host Command:   L   CR   LF
Quadrex 200 Response:  Partial Pressure of 1s index value,
                  ...,   Partial Pressure of last index value   CR   LF
```

This command fetches the Partial Pressure values according to the INDEX command. If more than one channel is selected by the INDEX command, a five-digit value, corresponding to NX.X 10^{-XX}, is sent for each channel. If ALTERNATE Partial Pressure is selected, the stored Partial Pressure values are sent.

"N" is an ASCII character of 0, 1, 2, or 3.
- 0 = Bad Partial Pressure data.
- 1 = Good Partial Pressure data.
- 2 = Bad Partial Pressure data at end of Gain range.
- 3 = Good Partial Pressure data at end of Gain range.

LIBRARY SPECTRA READ

```
Host Command:   K   2-digit LIB#    CR   LF
Quadrex 200 Response:  15 ASCII character Name
                  (3-digit Mass number 3-digit % for each of 6 channels)   CR   LF
```

This command sends a fifteen character Spectra name, followed by a Mass and % of that Spectra. Each Mass is a three-digit value and each % is a three-digit value. There are six sets of Mass and % values.

VERSION QUERY

```
Host Command:          V   CR   LF
Quadrex 200 Response:        4-digit value    CR   LF
```

The four digit version value transmitted to the host is the version number which also appears in the lefthand corner of the Quadrex 200 display screen when Quadrex 200 is initially powered to on. The first two digits represent the version number of the Quadrex 200 software (02 or greater), and the last two digits represent the version number of the IEEE Interface software currently installed in Quadrex 200 (50 or greater). .00 indicates no IEEE software/hardware installed. There is an implied decimal point between the first two digits and the last two digits - this decimal point appears on the Quadrex 200 screen, but is not transmitted in this response.

OPTION SWITCH VALUES

Host Command: O CR LF
Quadrex 200 Response: 3-digit options value CR LF

The values of all of the six configure switches on the microprocessor board may be obtained by the host with this query command. The values of these switches may only be queried, they are not programmable.

The value returned to the host is a three-digit decimal number ranging from 0 to 063, and is the sum of values denoting the switch positions, as follows.

Switch	Value if Open	Value if Closed
2-1	1	0
2-2	2	0
2-3	4	0
2-4	8	0
2-5	16	0
2-6	32	0

For example, if the Options value received from Quadrex 200 is 19, and since 19 = 1 + 2 + 0 + 0 + 16 + 0, the states of the switches are:

Switch No.	2-1	2-2	2-3	2-4	2-5	2-6
State	open	open	closed	closed	open	closed

For a description of the functions of these switches, refer to the section "Configuring and Adjusting the Quadrex 200" in the Quadrex 200 manual.

PROGRAM EXTRA RELAYS COMMAND

Host Command: R Data Value(s), 0-14 even... CR LF
Quadrex 200 Response: No Response

This command programs the three extra relays on the Relay I/O board (relays 10, 11 and 12). These relays are closed with an active high input and opened with an active low input. The sum of any of these values is valid data.

Relay Number	J1 Pin Numbers	Value To Open Relay	Value To Close Relay
10	5 and 23	0	2
11	15 and 32	0	4
12	14 and 33	0	8

Message Summary

To Change Status of Quadrex 200 Push Button

Use B command message (Change Status Command)
Use C command message (Push Button Command)

To Query Status of Quadrex 200 Push Button

Use H command message (Status command)
Use S command message (Status command)

To change the Display Screen on Quadrex 200

UNSTORED display: (a measurement mode display)
use M command message (Display Mode Command)

STORED display: (a MEM-X display)
use S/0/CR/LF command to query status of MEM-X
use B/2/CR/LF to go to MEM-X or
B/3/CR/LF to return from MEM-X

To Receive Parameter Value Information

UNSTORED display: (a measurement mode display)
use N command message (Normal Data Pointer)
and P command message (Parameter Pointer Command)
and F command message (Fetch Parameter Command)
use M command message (Display Mode Command)

STORED display: (a stored set of parameters)
use A command message (Alternate Data Pointer)
and P command message (Parameter Pointer Command)
and F command message (Fetch Parameter Command)

Remember BAR-SUBTRACT does not have stored parameters.

To change a Parameter Value at the Quadrex 200

UNSTORED displays only: (a measurement mode display)
use P command message (Parameter Pointer Command)
and U command message (Update Parameter Command

To Receive Quadrex 200 Data

UNSTORED data: (from the current measurement mode display)
use N command message (Normal Data Pointer)
and M command message (Display Mode Command)
and I command message (Index Command)
and either the T command message (Take Command)
or the G command message (Get Command)

STORED data: (from an alternate set of data)
use A command message (Alternate Data Pointer)
and D command message (Alternate Mode Pointer)
and I command message (Index Command)
and G command message (Get Command)

Partial Lockout of the Quadrex 200

There are times when Quadrex 200 is busy processing a command message sent to the Interface. Normally, for most commands sent by the host, this time is insignificant and will not be noticed nor will the time-delay involved be a limitation for the host in its communications with Quadrex 200. However some commands, due to the process involved at Quadrex 200, will take a considerable amount of time to complete.

If Quadrex 200 is busy processing a previously received command, this will be evident to the Quadrex 200 operator by the appearance of a lighted square on the Quadrex 200 screen, which will appear directly to the left of the title "MASS" on most of the display screen (bottom of the screen, near center). Also, all the front panel buttons except for COPY, RELAY, DEGAS, EMULT, EMIS, and POWER, will be inactive when the Quadrex 200 is busy processing a previous command. While this square is lit, indicating command processing is going on, any further command that may be inadvertently sent by the host will cause one or more communication, command errors.

To avoid causing an error (and avoid the necessity of sending a CNL message to clear the Interface of error), the host should allow enough time for the processing of each command. The end of each command is indicated by Eot or Nak. The commands that could take a long time to complete are any of the data retrieval commands (GET and TAKE); the INDEX command when it is pointing to a large interval of mass numbers and/or if the scan speed of the Quadrex 200 is set to Very Slow.

APPENDIX A

Examples of Computer Interfacing to Quadrex 200

A typical flow chart for handling communications between a computer and the Quadrex 200 is shown in Figure 8.4. The specific operations included in each step will depend on the computer, the use to be made of the data, and the action to be taken if errors are detected.

A sample program, written in HP-BASIC for an HP-85F computer is given below. In this program, commands are entered by the operator at the keyboard and data are displayed in raw form. This kind of program is useful in getting familiar with the communications system and can readily be modified to act as a subroutine in a larger program.

```
  1     ! *************************
  2     ! INITIALIZE HOST
  3     ! *************************
 10     CONTROL 10,1 ; 0 ! TURN OFF INTERRUPTS.
 20     CONTROL 10,2 ; 1 ! CLEAR TO SEND.
 30     CONTROL 10,3 ; 15 ! 9600 BAUD.
 40     CONTROL 10,4 ; 26 ! EVEN PARITY, CHAR. LENGTH OF 7.
 50     CONTROL 10,5 ; 48 ! ENABLE RECEIVE AND TRANSMIT
        HANDSHAKE.
 60     CONTROL 10,9 ; 129 ! ENABLE RECEIVER AND TRANSMITTER.
 70     CONTROL 10,16 ; 0 ! NO AUTOMATIC EOL SENT.
 80     DIM O$[20],I$[650],E$[20],C$[20]
 90     IOBUFFER O$
100     IOBUFFER I$
110     IOBUFFER E$
120     ! ^^^^^^^^^^^^^^^^^^^^^^^^^
130     ! INPUT AND FORMAT COMMAND
140     ! *************************
150     INPUT C$
160     IF C$="CANCEL" THEN O$=CHR$(24) @ GOTO 190 ! IS A
        CANCEL TO BE SENT?
170     IF C$="ESC" THEN O$=CHR$(27)&C$[4] @ GOTO 190 ! IS AN
        ESCAPE SEQUENCE COMMAND TO BE SENT?
180     O$=CHR$(2)&C$&CHR$(13) ! IF A NORMAL COMMAND TO BE
        SENT, ADD STX AND TRM.
190     !
200     ! *** TRANSMIT COMMAND ***
210     TRANSFER O$ TO 10 INTR
220     TRANSFER 10 TO I$ INTR ; DELIM 4
230     !
240     ! **** CHECK FOR ERRORS AND WAIT FOR ALL RETURNED
        DATA.****
```

```
250     STATUS I$,2 ; T2@ IF T2=0 THEN 310 ! CHECK IF INPUT
        BUFFER HAS RECEIVED ALL DATA.
260     IF POS(I$,CHR$(21))<>0 THEN 360 ! JUMP IF Nak RECEIVED.
270     IF POS(I$,CHR$(5))<>0 THEN 360 ! JUMP IF Enq RECEIVED.
280     GOTO 250 ! KEEP LOOPING.
290     !
300     ! **** COMMAND SUCCESSFULLY SENT, DISPLAY DATA. ****
310     DISP I$
320     CONTROL I$,0 ; 1,0 ! CLEAR SOURCE AND DESTINATION
        POINTERS IN BUFFER.
330     GOTO 140 ! NEXT COMMAND.
340     ! <><><><><><><><><><><><><><><><><><><><>
350     !
360     ! **** ERROR RECEIVED, FIND OUT WHAT IT WAS. ****
370     HALT 10 @ RESUME 10
380     !
390     O$=CHR$(24) ! SEND CANCEL.
400     TRANSFER O$ TO 10 INTR
410     TRANSFER 10 TO E$ INTR; DELIM 4
420     STATUS E$,2 ; T2@ IF T2<>0 THEN 420 ! WAIT UNTIL Eot
        RECEIVED.
430     CONTROL E$,0 ; 1,0 ! CLEAR SOURCE AND DESTINATION
        POINTERS.
440     !
450     O$=CHR$(2)&"SB"&CHR$(13) ! QUERY ERRORS.
460     TRANSFER 0$ TO 10 INTR
470     TRANSFER 10 TO E$ INTR; DELIM 4
480     STATUS E$,2 ; T2@ IF T2<>0 THEN 480 ! WAIT UNTIL Eot
        RECEIVED.
490     DISP E$ ! DISPLAY ERROR.
500     CONTROL E$,0 ; 1,0 ! CLEAR SOURCE AND DESTINATION
        POINTERS.
510     !
520     END
```

Figure 8.4

This section defines and provides operational information for the RS-232C communications Interface for the Quadrex 200.

The RS-232C Interface consists of internally installed components and does not use one of the option card slots described in Installing the Option Boards.

Information in Section 8 may be found in the following order:

INTRODUCTION

PORT TEST PROCEDURE

DEFINITION OF TERMS

CONNECTIONS

PROTOCOLS
- Basic Communication Protocol
- Control Character Protocol
- Message Protocol

INTERFACE CHARACTERISTICS

QUADREX 200 OPERATING FUNCTIONS
- Push-button Commands
- Control Commands
- Status of Quadrex 200 Conditions

QUADREX 200 OPERATING PARAMETERS

READING QUADREX 200 DATA
- Miscellaneous Messages
- Message Summary
- Partial Lockout of Quadrex 200

INTRODUCTION

The RS-232 Interface provides a means of electronic communication with Quadrex 200. Using suitable equipment, as described below, Quadrex 200 can be operated from a remote location, can be operated without operator intervention, and can be integrated into computer controlled instrumentation systems. Data from Quadrex 200 can also be acquired, manipulated, and stored by computer equipment.

When communicating with an external device through the RS-232 Interface, the external device is required to assume the role of "Host" and Quadrex 200 acts as the "peripheral" device. The host issues commands to Quadrex 200 to change state or to respond with data to be read by the host. The host device will normally be a computer which has been programmed to issue suitable commands to Quadrex 200.

In order that the host and Quadrex 200 can communicate successfully, they must operate using a common set of rules (protocols). These protocols are divided into three major categories in this chapter:

Basic Communication Protocols - necessary to install and operate a communications link.

Control Character Protocols - necessary to define message handling routines.

Message Protocols - necessary to specify the action that Quadrex 200 is to perform.

PORT TEST PROCEDURE

The Interface software includes an optional self-test procedure which may be followed at any time the RS-232 ports of Quadrex 200 need to be tested for basic operational status. Without following the procedure to be outlined here, no self-test of the two ports is carried out; it is the choice of the operator to do this test. It is recommended that the operator follow through this procedure initially before interfacing Quadrex 200 with a host computer, and any time thereafter when such trouble-shooting is desired.

The test by the Interface consists of the transmission of the message "INFICON QUADREX 200 SELF TEST" to one of the two RS-232 ports of the Quadrex 200. This message is received and compared to the message sent within a set amount of time. The Test result then appears on the Quadrex 200 display screen.

Either of the two RS-232 ports, A or B (Main or Auxiliary, respectively) may be tested with this procedure:

1. Quadrex 200 Power off.

2. Connect the self-loop connector to the port to be tested. This connector is supplied with the Quadrex 200.

3. The right and left cursor keys on the Quadrex 200 front panel are used in the test. The right cursor key is associated with Port B, or the Auxiliary RS-232 port. The left cursor key is associated with Port A, or the Main RS-232 port. Press and hold the appropriate cursor key and turn Quadrex 200 power on.

4. The following display will appear briefly on the Quadrex 200 screen:

INFICON VIDEO SYSTEM V.#

BEGIN COM TEST

5. A successful test of the port tested will be indicated by the message "A-PORT OK" or "B-PORT OK" in the lower left-hand corner of the screen, replacing the original message "BEGIN COM TEST."

6. An unsuccessful test of a given port will be indicated by the message "A-PORT FAIL" or "B-PORT FAIL" in the lower left-hand corner of the screen, replacing the original message "BEGIN COM TEST." If the "BEGIN COM TEST" message remains on the screen, the Quadrex 200 transmit enable line (CTS) is disabled, which is also an error condition. If any indication of failure is observed, contact the Inficon Service Department.

DEFINITION OF TERMS

In the discussion below, a number of terms will be used to describe features used in communication:

Serial Communication

The individual bits of information that make up a command or data message are sent in series on a single wire. In an actual communications link between a host and Quadrex 200, at least three wires are used, more typically five, to provide two-way communication, a common ground, and preferably, some control signals.

RS-232

The Interface conforms to the EIA Standard RS-232 and the very similar European Standard CCITT V.24 for serial communications. These standards describe the electrical connections, electrical characteristics, and controlling functions of interfaces.

Bits, Bytes, and Characters

The minimum unit of information in computers is called a bit (binary digit); a bit has one of two values, usually denoted as 0 and 1, which are electrically distinguished as two voltage levels. A byte is a group of 8 bits normally handled as a unit. In the Quadrex 200 communication system, a byte represents one character, which is a letter, numeral, punctuation mark or control character.

Control Characters

In addition to letters, numerals and punctuation marks, the ASCII character set includes 32 codes that can be recognized by computer equipment for special purposes. In the Quadrex 200 communication system some of these are assigned as communications controls, such as indicating the end of messages, for example. The control codes will be discussed in detail in the section on communication rules.

Baud

The rate, in bits per second, at which information is sent is called the baud rate. In order for information to be received correctly, the host and Quadrex 200 must operate at the same baud rate. A variety of commonly used baud rates are available in Quadrex 200; selection of the desired rate is accomplished with internal switches.

Start, Parity, and Stop Bits

The RS-232 Standard defines an asynchronous form of communication, in which characters are sent one-at-a-time with no fixed interval between them. Since the group of 8 bits used to identify a character may start with a 1 or 0, the group is preceded by a start bit which is always 0 and followed by one or more stop bits which are always 1's. The transition from the 1 level to the 0 level signals the receiver that a character follows. In the main body of the character code, 7 bits are sufficient to define the 128 available characters; the 8th bit is called the parity bit and can be used for error detection by programming the instruments so that the sum of the 8 bits is even (or odd).

Handshaking

Handshaking is used to prevent the transmitting device from sending characters when the receiving device is "busy" and the message would not be received correctly. Quadrex 200 supports software and hardware handshaking. Software handshaking is accomplished in the host by using the echo mode of operation of Quadrex 200 and programming the host so that it does not send a character until Quadrex 200 has responded (echoed) to indicate that the preceding character has been received and processed. Hardware handshaking is accomplished with three additional wires by which the host and Quadrex 200 signal that they are ready to receive the next character.

Connections Upper Case Bold

Quadrex 200 incorporates a standard 25 pin female connector for connection to the host, and is wired as a DTE (Data Terminal Equipment) device. Note that the CTS (Clear to Send) line must be driven to Binary 0 (positive voltage > 3 volts and < 15 volts) in order for the Quadrex 200 to transmit to the host. In a hardware handshaking system, the CTS line should be used by the host to control the activity of the Quadrex 200 transmitter. In a similar manner, the RTS (Request to Send) output from Quadrex 200 is intended to control the host transmitter. For successful hardware, handshaking the transmitter of the host device must be controllable on a character-by-character basis.

PIN #	Name	Description	Signal Flow	Notes
2	TxD	Data transmitted by Quadrex 200	From Quadrex 200 to the host	
3	RxD	Data received by Quadrex 200	From the host to Quadrex 200	
4	RTS	Request to Send	From Quadrex 200 to the host	Binary 0 when the Quadrex 200 is ready to receive a character
5	CTS	Clear to Send	From the host to the Quadrex 200	When held to Binary 0, this line enables the Quadrex 200 to transmit data
7	GND	Ground	Common (required)	Always Connect

(Cont'd)

PIN #	Name	Description	Signal Flow	Notes
8	DCD	Data Carrier Detect	From the host to Quadrex 200.	Binary Ø enables receiver on Quadrex 200. Binary 1 causes Quadrex 200 to ignore incoming characters
13	TxRxC	Baud Clock	From the Quadrex 200 to the host	Frequency is 16 x the baud rate; use is optional
20	DTR	Data Terminal Ready	From the Quadrex 200 to the host	Binary 0 when the Quadrex 200 is On.

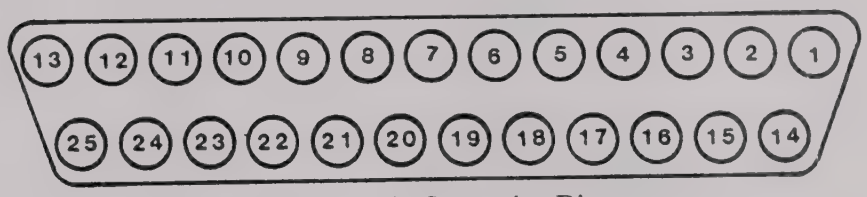


Figure 8.1 Pin Connection Diagram

PROTOCOLS

Basic Communication Protocols

These protocols describe the electrical and mechanical requirements for the transmission of data.

These protocols consist of a definition of the voltage levels used to represent signals, available baud rates, the character format used, and the identification of pin connections. The voltage levels are conventional and compatible with standard RS-232 devices.

The Quadrex 200 and host must operate at the same baud rate. To set the Quadrex 200 baud rate, it is necessary to use a selector switch located on the CPU board inside Quadrex 200. See Section 3 in the Quadrex 200 manual for instructions on accessing the CPU board. The baud rate selector switch is located at the upper right as shown in Figure 8.2. Be sure only one switch segment has been selected; the unit will not operate correctly if more than one baud rate selector is active.

The host must be configured to match the character format of Quadrex 200.

Voltage Level:	Binary 0	+3 to 15V
	Binary 1	-3 to -15V

Baud Rate Options:	150	2400
	300	4800
	600	9600
	1200	19200

Character Format: 10 bit frame
1 start bit
7 data bits
1 parity bit
1 stop bit

NOTE: Quadrex 200 does not normally check parity on input, but can be commanded to check for even parity. Quadrex 200 transmits characters with parity even.

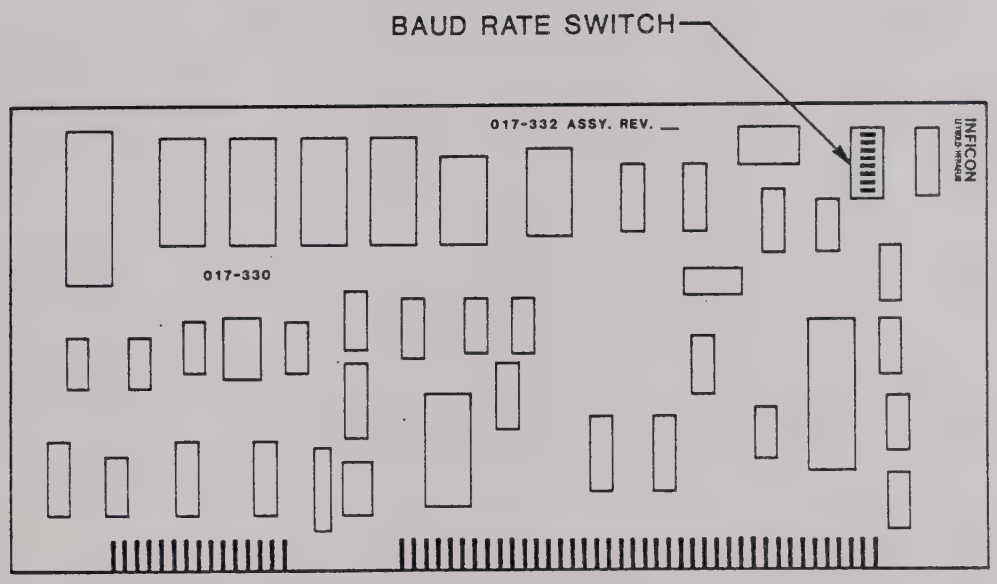


Figure 8.1 CPU Board and Baud Rate Switch

Control Character Protocol

This section describes the control characters used in communications between the host and Quadrex 200. These control characters make it possible for the host to verify that its commands have been transmitted to Quadrex 200 and acted upon.

The host must insert the proper control characters into all messages. In addition, the host should be programmed to receive and process control characters sent by Quadrex 200 so that the action of the host may properly take into account the state of Quadrex 200. For example, if the host has queried Quadrex 200 for an item of data, it must not send another command until Quadrex 200 has completed its response.

It should also be noted that the names used to specify control characters are generic. On start-up, Quadrex 200 uses ASCII characters conventionally assigned to these functions. These assignments can be changed (in most cases) by a command from the host if different characters are more conveniently used by the host. For example, Quadrex 200 normally assigns the carriage-return (13 Decimal) as a message terminator (TRM). Some host devices are designed to recognize a line-feed (10 Decimal) for this purpose. Thus the host may have built-in features for handling some or all of the control character protocols described below.

Before looking at the details of the system of control characters, it is useful to consider a brief outline of a typical communications sequence:

1. QUADREX 200 IS RUNNING - There are no messages being handled.

2. HOST ORIGINATES A COMMAND MESSAGE - The host sends a character by character command message beginning with STX (Start Character) or ESC (Escape Character). Quadrex 200 will respond with a Uns (Unit separator) indicating a command is being built. Each character the host sends after this is acknowledged as received with a Uns being sent to the host, if echo is on, until the termination character. The termination character is TRM for STX command messages or the last character sent in ESC command messages. The termination charcter received by Quadrex 200 always prompts an Ack (Acknowledge character) to be sent to the host. If no Ack character is sent by Quadrex 200 then no command is processed.

3. QUADREX 200 PROCESSES COMMAND MESSAGE - After the Ack character is sent to the host the command message is processed and any data is sent one character at a time. If hard handshaking is not implemented then the host must be able to accept the data as fast as the Quadrex 200 sends it. When no data is requested then the command is performed as described.

4.a. COMMAND MESSAGE EXECUTED - The final response of the Quadrex 200 on a valid command is the Eot (End of transmission character). The Eot character comes after data or the Ack character.

4.b. COMMAND MESSAGE NOT EXECUTED - The final response of the Quadrex 200 on an invalid command is the Nak (Not acknowledged character). The Nak character almost always comes after the Ack character and means the command was invalid. After Nak a CNL (Cancel Command) command must be sent before another command is attempted.

The operation of the Interface is described by the State Diagram, Figure 8.3.

The Interface is always in one of six possible states: POFS, IDLS, BDLS, ITPS, ERIS, and ERRS (definitions found in Table 1). The diagram then defines all possible paths of transition from state to state, indicating the cause of the transition and the resulting Quadrex 200 output. This information is also presented in tabular form (Table 2). By tracking the sequence of Quadrex 200 responses, the host can monitor the state of the Interface and take appropriate corrective action in the case of communication or command errors.

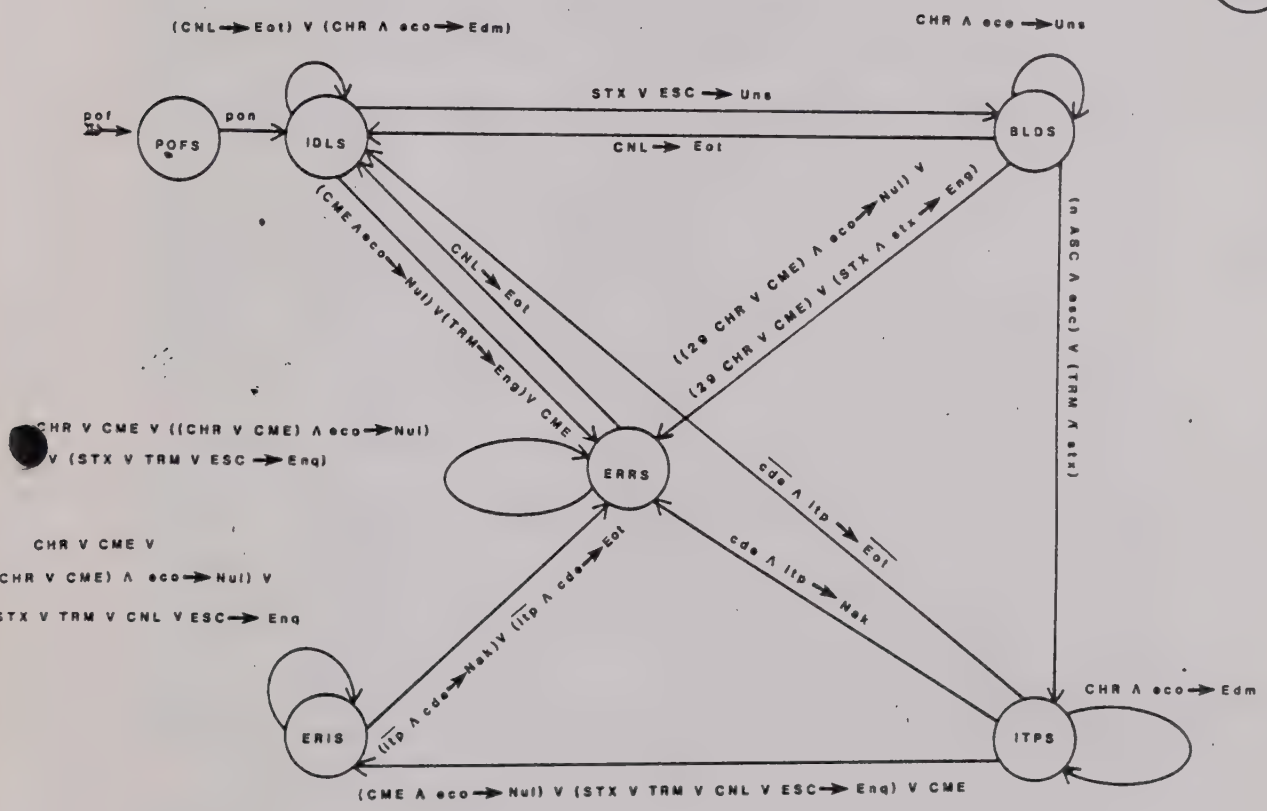


Figure 8.3 State Diagram

TABLE 1 - STATE DIAGRAM LEGEND

Quadrex 200 internal conditions (3 lower case letters)

itp	Interpreting and processing message
eco	Software handshake is enabled
pon	Power on
pof	Power off
stx	First character in string is STX
esc	First character in string is ESC
cde	Command error (invalid command or sequence)

Message sent to host (1 upper case, 2 lower case letters)

Ack	Acknowledge character
Nak	Non-acknowledge character
Edm	End medium character
Eot	End of transmission character
Enq	Enquiry character
Nul	Null character
Uns	Unit separator character

Character received at Quadrex 200 (3 upper case letters)

ASC	Any ASCII character
CHR	Any ASCII character other than the four special control characters
CME	Communication error, overrun, framing error, or parity error (if parity checking is enabled)
CNL	Cancel command (a special control character)
ESC	Escape character (a special control character)
STX	Start character (a special control character)
TRM	Termination character (a special control character)

A state the communications is in (4 upper case letters)

POFS	Power off state
IDLS	Idle state
BLDS	Building command state
ITPS	Interpreting command state
ERIS	Error occurred while interpreting, and continue interpreting
ERRS	Error state

Logical symbols and special characters

n	Count of an Escape sequence
v	Logic OR
^	Logic AND
→	Logic Implies
$\overline{\text{condition}}$	Logic Complement (negation of the condition)

TABLE 2 - STATE DIAGRAM SUMMARY

STATE	HOST SENDS	QUADREX 200 REPLIES	NEXT STATE	REMARKS
POFS	-	-	IDLS	Transition on power up
IDLS (idle)	STX	Uns	BLDS	Start of command
	ESC	Uns	BLDS	Start of escape sequence
	CNL	Eot	IDLS	Cancel with nothing to cancel
	TRM	Enq	ERRS	No message: only terminator
	CME	Nul*	ERRS	Defective character
	CHR	Edm*	IDLS	Message must start with either STX or ESC
BLDS (build string)	CHR	Uns*	BLDS	Part of message and no defects
	CNL	Eot	IDLS	Cancel message built so far
	STX	Enq	ERRS	Busy with previous message
	ESC	Enq	ERRS	Busy with previous message
	CME	Nul*	ERRS	Defective character
	29CHR	Nul*	ERRS	Buffer overflow: max. length=29
	TRM	Ack	ITPS	End of Command
	nASC	Ack	ITPS	End of Escape sequence reached with nth (=count) character
ITPS (inter-pret & process string)	CHR	Edm*	ITPS	Busy processing previous message
	CME	Nul*	ERIS	Defective character received while busy with previous message
	STX	Enq	ERIS	Busy processing previous message
	ESC	Enq	ERIS	Busy processing previous message
	TRM	Enq	ERIS	Busy processing previous message
	CNL	Enq	ERIS	Cancel command invalid while busy processing previous message
		Eot	IDLS	Processing of valid message complete
		Nak	ERRS	Processing of invalid message is complete

*Quadrex 200 software handshake is on

STATE	HOST SENDS	QUADREX 200 REPLIES	NEXT STATE	REMARKS
ERIS (error	CHR	Nul*	ERIS	Previously had an error, and busy processing
while interp)	CME	Nul*	ERIS	Defective character received when already had an error, and busy processing
	STX	Enq	ERIS	Previously had an error and busy processing
	ESC	Enq	ERIS	Previously had an error and busy processing
	TRM	Enq	ERIS	Previously had an error and busy processing
	CNL	Enq	ERIS	Previous message is still in process; no cancel is effected
		Nak	ERRS	Processing of invalid message is complete; previous error must be cleared
		Eot	ERRS	Processing of valid message is complete; previous error must be cleared
ERRS	CNL	Eot	IDLS	Cancel to clear out the error
(error	CHR	Nul*	ERRS	Previously had an error that
state)				must be cleared
	CME	Nul*	ERRS	Previously had an error that must be cleared
	STX	Enq	ERRS	Previously had an error that must be cleared
	ESC	Enq	ERRS	Previously had an error that must be cleared
	TRM	Enq	ERRS	Previously had an error that must be cleared

*Quadrex 200 software handshake is on

Message Protocols

GENERAL FORMAT OF ALL VALID MESSAGES

All messages sent by the host are strings of ASCII characters and start with either the control character STX, or the control character ESC. The contents of command messages and escape sequence messages will be treated separately.

> CAUTION: In certain descriptions of messages in this manual, the slash character ('/') will be used for demonstration purposes to separate the different parts of the message. The slash ('/') should NOT be included in the actual messages sent to the Interface, as this will result in a command error.

STX marks the beginning of a message to the Interface called a command; commands direct Quadrex 200 to perform specific functions and to query Quadrex 200 for status information and measured data. The end of a command is always indicated by the TRM character.

> NOTE: All replies are with echo on (software handshaking).

The general format of a command message is:

Host Command:	STX	Command Character	Contents of Command...	TRM		
Quadrex 200 Response:		Uns	Uns	Uns...	Ack	Eot

ESC marks the beginning of a message called an escape sequence; escape sequences allow the host to alter some of the characteristics of the interface itself. A count character must appear in the escape sequence directly after the ESC character; this count character is an indicator of how many more characters that follow, and form part of the escape sequence. Valid count characters are 1...9, A...F ASCII (corresponding to 1...15 decimal), with further limitations depending on the particular escape sequence. The general format of an escape sequence is:

Host Escape Sequence:

	ESC	Count	Type Character	List of Characters...	Last Character		
Quadrex 200 Response:		Uns	Uns	Uns	Uns...	Ack	Eot

Quadrex 200 responds to the start and end of each message from the host, confirming that the message has been received. In addition, the Quadrex 200 may be commanded to respond to every character from the host (software handshake).

In the next sections each command and escape sequence is described, along with the normal Quadrex 200 response. Responses that result from error conditions and with software handshaking off are described in the section on the State Diagram.

NOTE: CANCEL COMMAND (CNL) is a special one character command that can terminate an STX command message before the TRM character is sent. It has no use in an ESCape sequence. The Cancel Command (CNL) also removes the host from the error state (ERRS). Cancel Command (CNL) is acknowledged with Eot.

INTERFACE CHARACTERISTICS

Certain characteristics of the Quadrex 200 RS-232 Interface are programmable by the host with the messages that are described in this section.

Soft Handshake or Echo

Host - Escape Sequence:	ESC	2	E	0 *		
Quadrex 200 Response:		Uns	Uns	Uns	Ack	Eot
Host - Escape Sequence:	ESC	2	E	1 **		
Quadrex 200 Response (echo is off):		Uns			Ack	Eot

*to turn OFF Soft Handshaking
**to turn ON Soft Handshaking

The soft handshake is set to ON when Quadrex 200 and Interface are powered-up. With the handshake on, the Interface will respond to every character sent by the host with a specific character, as described in detail in the State Diagram.

If the soft handshaking is off, the only characters which will demand a response from the Interface to the host are the four special control characters STX, ESC, TRM, and CNL as well as the last character of an escape sequence.

Program Special Characters

Host - Escape Sequence:	ESC	A	C	TRM	Nul	STX	Eot	Enq	Ack	Nak	Edm	Uns	
Quadrex 200 Response:	Uns	Uns	Uns	Uns	Uns	Uns	Uns	Uns	Uns	Uns	Uns	Ack	Eot

The nine Special Characters named TRM, Nul, STX, Eot, Enq, Ack, Nak, Edm, and Uns, are assigned default character values by the interface on Quadrex 200 power-on. These character assignments, which are listed in the table below, may be changed by programming the character names to have other ASCII character values. To change the character assignment of any of the names listed, a fixed character list of nine character representations must be given in this escape sequence in the order in which the names are listed below, including both the new values of the characters to be changed and the default values of the characters to remain the same.

Name of ASCII Character	Default Value, Hexidecimal	Default Value, Decimal
TRM	0D	13
Nul	00	0
STX	02	2
Eot	04	4
Enq	05	5
Ack	06	6
Nak	15	21
Edm	19	25
Uns	1F	31

Examples:

1. If all nine characters must be changed from their default values to other ASCII values, then the escape sequence would include the nine new character values to be substituted for the named characters as listed in the order given.

2. If a single character at any point in the list is to be changed, then the list of character values would consist of all the default values except for the one character to be changed. In particular - if only the Eot character is to be changed from its default value of 4 (decimal) to a value of 10 (decimal), which is an ASCII linefeed character, then the list of characters would include the default values for all characters except for the fourth position in the character list, which would now be represented by a decimal 10.

The choices for values of any of the nine character names should be made such that none of the characters is one that is likely to appear in either the data from Quadrex 200 (i.e. numerals 0 through 9), or in the contents of one of the other escape sequences or one of the command messages (i.e. alphabetical and numerical characters). Also, no two of the nine character names should be given the same value.

Parity Error Handling

```
Host Escape Sequence:          ESC  2  M  1  *
Quadrex 200 Response:                 Uns Uns Uns Ack  Eot

Host Escape Sequence:          ESC  2  M  0  **
Quadrex 200 Response:                 Uns Uns Uns Ack  Eot
```

*to detect even parity errors of characters from host
**to ignore parity errors

Parity error detection of characters from the host is defaulted to off with Quadrex 200 power-on, so that parity of characters is ignored.

QUADREX 200 OPERATING FUNCTIONS

Any of the basic operating functions that are manually controllable by Quadrex 200 push buttons may be programmed, or their status queried, by the host. The host may also choose whether or not changes may be made locally using the push buttons themselves.

Push Button Commands

```
Host Command:        STX  C  control character  TRM
Quadrex 200 Response:     Uns Uns                Uns  Ack  Eot
```

Controlling the ON and OFF conditions of the Quadrex 200 front panel buttons is a matter of choosing one of sixteen characters corresponding to a unique Quadrex 200 operating function, and including that character in the contents of the command message. The valid control characters and their corresponding Quadrex 200 events are:

Quadrex 200 Event	Control Character
Electron Multiplier On	1
Electron Multiplier Off	2
Degas On	3
Degas Off	4

Quadrex 200 Event	Control Character
Emission On	5
Emission Off	6
Relays On	7
Relays Off	8
Test On (Quadrex screen must be in MENU mode)	9
Test Off (Quadrex screen must be in MENU mode)	A
Store Spectrum (Screen must be in modes 1-5)	B
Reset Key Action	C
Copy Quadrex display screen	D
Short Copy: send amplitude data**	E
Copy Kill: cancel XY-recorder data after plotter has finished	F

**If the MENU is on the Quadrex 200 display screen, then the version number of the Interface, the values of the configuration switches, and the copyright are sent to the plotter.

Control Commands

Host Command: STX B control character TRM
Quadrex 200 Response: Uns Uns Uns Ack Eot

Quadrex 200 Event	Control Character
Go to MEM-X (Quadrex 200 must be displaying modes 1-5)	2
Return from MEM-X	3
Partial front panel lock (Locks all keys except COPY, RELAY, DEGAS, EMULT, EMIS and POWER button)	4
Unlock front panel (Enables all front panel keys)	5

Status of Quadrex 200 Conditions

Host Command: STX S control character TRM
Quadrex 200 Response: Uns Uns Uns Ack value of the status of the condition selected in this command message Eot

The current status - on or off value, or numeric value - of any of the Quadrex 200 operating conditions may be individually queried by the host.

The condition characters assigned and the expected responses to this command are:

Quadrex 200 Condition	Condition Character	Response Field
MEM-X QUERY	0	one digit (0,1)
ELECTRON MULTIPLIER QUERY	1	one digit (0,1)
DEGAS QUERY	2	one digit (0,1)
EMISSION QUERY	3	one digit (0,1)
COPY QUERY	4	one digit (0,1)
HEAD STATUS	5	three digits
PRESSURE VALUE	6	three digits
MEASUREMENT MODE & TEST STATUS	7	three digits
DISPLAY MODE	8	three digits
CURSOR LOCATION	9	three digits
RELAY STATUS	A	one 3-digit or two 3-digit values
COMMUNICATION, COMMAND ERRORS	B	two 3-digit values
Is the RANGE MSG ON	C	one digit (0,1)

The response to the first five queries is a single digit indicating whether the function is ON (= 1) or OFF (= 0).

Formats of the other responses are:

HEAD STATUS - A three digit value equal to the sum of any of the following values corresponding to the conditions listed (with preceding zeros if the sum is a value less than 3 digits).

Status Condition	Value if True	Value if False
cathode voltage low	1	0
cathode voltage high	2	0
anode voltage high	4	0
anode voltage low	8	0
emission failure	16	0
RF failure	32	0
Cable not on	64	0
pressure failure	128	0

PRESSURE VALUE - A three digit value: the first and second digits are the significant digits of the pressure value, and a decimal point is assumed (but not transmitted) between the first and second digit. The third digit is the value of the negative exponent of 10 of the pressure value. For example, if the host queries the pressure value with the STX/S/6/TRM message, and if the response is 117, then the pressure value reading is 1.1×10^{-7} torr.

MEASUREMENT MODE AND TEST STATUS - The response to this query is either a value between 1 and 6 (with 2 preceding zeros) or a value between 129 and 134, as listed below with their corresponding meanings. The response indicates which Quadrex 200 mode is currently being measured, regardless of the display (Display mode may be MENU, USER LIBRARY or SPECTRA LIBRARY and Measurement mode may be one of those listed below).

Response from Quadrex 200	Meaning
001	Test off, ANALOG Mode Measured
002	Test off, BAR-GRAPH Mode Measured
003	Test off, TABLE Mode Measured
004	Test off, LEAK CHECK Measured
005	Test off, PARTIAL PRESSURE Mode Measured
006	Test off, BAR-SUBTRACT Measured
129	Test on, ANALOG Mode Measured
130	Test on, BAR-GRAPH Mode Measured
131	Test on, TABLE Mode Measured
132	Test on, LEAK CHECK Measured
133	Test on, PARTIAL PRESSURE Mode Measured
134	Test on, BAR-SUBTRACT Measured

DISPLAY MODE - This response is a value from 0 through 8 (with 2 preceding zeros) corresponding to the nine different Quadrex 200 displays. Normally, Display mode is the same as Measurement mode (above), except when MENU, USER LIBRARY, and SPECTRA LIBRARY are on the Quadrex 200 screen.

Response from Quadrex 200	Meaning
000	The MENU is on the Quadrex 200 screen
001	ANALOG display is on the screen
002	BAR-GRAPH display is on the screen
003	TABLE display is on the screen
004	LEAK CHECK display is on the screen
005	PARTIAL PRESSURE is on the screen
006	BAR-SUBTRACT display is on screen
007	USER LIBRARY is on screen
008	SPECTRA LIBRARY is on the screen

CURSOR LOCATION - This response is a three digit value. If the cursor is on the screen, then the value returned is equal to the number (with preceding zeros) assigned to the parameter on which the cursor is positioned. The parameter numbers are listed in the PARAMETER POINTER command for each parameter. If the cursor is off the screen, then either the value of 254 or 255 is sent.

RELAY STATUS - This response is two 3-digit values if the input/output type relay board is installed, or one 3-digit value if the output only relay board is installed, equal to the sum of any of the values listed in the table below (with preceding zeros if the sum is less than 3 digits). A response of 000, or 000 000, indicates that all relays are open, and relays are disabled.

Value Relay Open (First 3 Digits)	Value Relay Closed	Relay
0	1	Relay 1 (channel 1)
0	2	Relay 2 (channel 2)
0	4	Relay 3 (channel 3)
0	8	Relay 4 (channel 4)
0	16	Relay 5 (channel 5)
0	32	Relay 6 (channel 6)
0	64	Relay 7: if open, Relays 1-6 are disabled; if closed, Relays 1-6 are enabled
0	128	Relay 8: system valid relay

(Second 3 digits) for I/O Relay Board

0	1	(not used)	Relay 9
0	2	User Relay 1	Relay 10
0	4	User Relay 2	Relay 11
0	8	User Relay 3	Relay 12

Relay 8, if open, indicates that the Quadrex 200 is in an invalid state for taking data. If Relay 8 is closed, then the Quadrex 200 satisfies all of the following conditions: emission is on, test mode is not on, degas is not on, no system failure messages appear on the Quadrex 200 crt screen, and electron multiplier is on if present.

COMMUNICATION, COMMAND ERRORS - This response consists of two 3-digit values. Error values other than 000,000 indicate that one or more errors related to the communications protocol or the command processing has occurred. Only the first error encountered is kept for each communication or command error. All errors after the first are disregarded by the Quadrex 200.

First 3-Digits Error Values (communication error)

Error Value	Value if No Error	Condition, if Error
065	0	Too many characters in build: maximum length (29) exceeded
066	0	TRM sent at wrong time
067	0	CNL sent at wrong time
068	0	STX sent at wrong time
069	0	Parity error, character received did not have even parity
070	0	Overrun error
071	0	Framing Error
072	0	ESC sent at wrong time
073	0	Invalid count character for escape sequence (1...F valid)
074	0	Output buffer overflow, Quadrex 200 transmitter disabled and more than 2 characters to respond. This error puts "HOST ERROR 20" to video display.

Second 3-Digits Error Value (command errors)

Error Value	Value if No Error	Command Error Condition
001	0	Illegal command
002	0	Illegal data
003	0	Illegal begin and/or end index for either the current mode or for the command
004	0	Illegal select mode pointer (1..5 are valid)
005	0	Illegal display mode is on the Quadrex 200 screen for the attempted event

Second 3-Digits Error Value (command errors) (cont'd)

Error Value	Value if No Error	Command Error Condition
006	0	Illegal count for the particular escape sequence
007	0	Illegal programmable parameter
008	0	Invalid stored parameter number (BAR-SUBTRACT, USER LIBRARY parameters)
009	0	Pressure not displayed due to emission off or degas on
010	0	Invalid relay command, board not installed
011	0	Copy requested when copy is already running
012	0	Degas requested when emission is off
013	0	Electron multiplier requested when not in unit or emission is off

Status of Quadrex 200 Conditions (continued)

Host Command: STX H control character TRM
Quadrex 200 Response: Uns Uns Uns Ack data associated with this command message Eot

Quadrex Event	Condition Character	Response Field
READ I/O RELAY BOARD CONNECTOR J2	6	two 3-digit values
READ SCAN TIME	7	7-digit value

READ I/O RELAY BOARD

The first 3-digits are equal to the sum of any pin inputs 13 through 20. The second 3-digits are equal to the sum of any pin inputs 21 through 24. These inputs are active low so a zero in any pin number means this pin is acted upon.

First 3-digits from Quadrex 200

Pin Number	Function It Performs	Value If Active	Value If Not Active
13	Turn relays on	0	1
14	Turn relays off	0	2
17	Turn emission on	0	4
15	Turn emission off	0	8
16	Turn degas on	0	16
18	Turn degas off	0	32
19	Turn electron multiplier on	0	64
20	Turn electron multiplier off	0	128

Second 3-digits from Quadrex 200

Pin Number	Function It Performs	Value If Active	Value If Not Active
24	Copy request	0	1
23	Peak find request	0	2
22	No function	0	4
21	No function	0	8

READ SCAN TIME

This command sends the total scan time in milliseconds, for the current measurement mode.

QUADREX OPERATING PARAMETERS

These messages allow the host to point to any Quadrex 200 operating parameter values, to point to either actual or alternate data, and to either query the present value or command a change to be made in the value.

Normal Data Pointer

Host Command: STX N TRM
Quadrex 200 Response: Uns Uns Ack Eot

The currently measured (normal) Quadrex 200 data is selected, as opposed to the stored (alternate) data. All subsequent commands and queries concerning Quadrex 200 operating values and spectrum values will reference the current Quadrex 200 data. This normal data set is the default set pointed to on Quadrex 200 power-on.

The command messages affected by this command are: FETCH, GET, PARTIAL PRESSURE READ, and the STATUS command for HEAD STATUS, PRESSURE VALUE, or SCAN TIME.

Alternate Data Pointer

```
Host Command:          STX   A   TRM
Quadrex 200 Response:        Uns  Uns   Ack   Eot
```

Sending this message identifies to the Interface that the alternate (stored) data are to be used for all subsequent queries. This is opposed to the Normal, or current Quadrex 200, data values (see Normal Data Pointer Command). The default data set referenced on power-on of the Quadrex 200 and the Interface is the Normal set of data.

The subsequent commands that are affected by this pointer command are: FETCH, GET, PARTIAL PRESSURE READ, and STATUS command for HEAD STATUS, PRESSURE VALUE, or SCAN TIME.

Display Mode Change

```
Host Command:          STX   M   Display Character   TRM
Quadrex 200 Response:        Uns  Uns              Uns      Ack   Eot
```

Any one of the eight unstored display modes may be commanded to appear on the Quadrex 200 crt screen.

To display a mode on the Quadrex 200 screen, MEM-X must not be on, and one of the following display characters must be given in this Display Mode Change command:

Quadrex Display Mode	Display Character
MENU	0
ANALOG	1
BAR-GRAPH/LIB	2
TABLE	3
LEAK CHECK	4
PARTIAL PRESSURE	5
BAR-SUBTRACT	6
USER LIBRARY	7
SPECTRA LIBRARY	8

Alternate (Stored) Mode Pointer

```
Host Command:          STX   D   Display Character   TRM
Quadrex 200 Response:        Uns  Uns              Uns      Ack   Eot
```

Any of the five stored displays may be chosen with this command message as the referenced display for subsequent data queries sent to Quadrex 200, by selecting one of the display characters listed below. This command refers strictly to the Alternate (stored) data set, and thus is not dependent on the data set pointed to previously. The only commands affected by this pointer are the GET command, and the STATUS command for PRESSURE VALUE, HEAD STATUS, or SCAN TIME.

ALTERNATE Display	Display Character
ANALOG	1
BAR-GRAPH/LIB	2
TABLE	3
LEAK CHECK	4
PARTIAL PRESSURE	5

Parameter Pointer

Host Command: STX P Parameter Character(s)... TRM
Quadrex 200 Response: Uns Uns Uns... Ack Eot

Any of the Quadrex 200 parameter values, normal or frozen, may be selected. Any subsequent FETCH or UPDATE command messages will depend on which parameter is pointed to by this command.

General Parameter Numbers

Display Mode	Gain	Scan	EM Voltage	Mass Center	Width
ANALOG	0	1	2	3	4
BAR-GRAPH/LIBRARY	5	6	7	8	9
TABLE	---	11	12	---	---
LEAK CHECK	43	44	45	46	---
PARTIAL PRESSURE	---	48	49	---	---
BAR-SUBTRACT	161	162	163	164	165
USER LIBRARY	---	---	---	---	---

General Display Parameter Numbers

Display Mode	LIB#	Volume	Pressure Unit	Pressure Sensitivity	Pressure Exponent
BAR-GRAPH/LIBRARY	10	---	---	---	---
LEAK CHECK	---	47	---	---	---
PARTIAL PRESSURE	---	---	50	51	52

TABLE Display Parameter Numbers

Parameter	Channel 1	Channel 2	Channel 3	Channel 4	Channel 5	Channel 6
GAIN	13	18	23	28	33	38
CALIBRATION	14	19	24	29	34	39
LOW LIMIT	15	20	25	30	35	40
HIGH LIMIT	16	21	26	31	36	41
MASS	17	22	27	32	37	42

PARTIAL PRESSURE Display Parameter Numbers

Channel	GAIN	MASS	FACTOR
1	53	54	55
2	56	57	58
3	59	60	61
4	62	63	64
5	65	66	67
6	68	69	70
7	71	72	73
8	74	75	76
9	77	78	79
10	80	81	82
11	83	84	85
12	86	87	88

USER LIBRARY Parameter Numbers

LIB#	MASS 1-6	% 1-6
1	89-94	101-106
2	95-100	107-112
3	113-118	125-130
4	119-124	131-136
5	137-142	149-154
6	143-148	155-160

UPDATE THE PARAMETER POINTER

Host Command: STX U Data Characters... TRM
Quadrex 200 Response: Uns Uns Uns... Ack Eot

The Update command allows the host to send selected values to Quadrex 200 for any of the programmable parameters listed in the description of the Parameter Pointer command, except for the five BAR-SUBTRACT parameters (parameter numbers 161 through 165, and Partial Pressure Gain parameters for the first six masses). The value of the parameter currently pointed to is changed with this command.

All parameters, except those listed above, are programmable with this command. The data fields are as follows for each of the seven types of parameters:

ELECTRON MULTIPLIER VOLTAGE - The acceptable values for the electron multiplier data field range from 100 to 300 with increments of 1 unit, corresponding to the Quadrex 200 electron multiplier voltages of 1000 to 3000 volts.

The format for updating the electron multiplier voltage is:

STX/U/three digit value/TRM

SCAN - A single digit equal to a 0, or 1, or 2, or 3, or 4 corresponding to the following speeds:

0 ... very slow
1 ... slow
2 ... normal
3 ... fast
4 ... very fast

The format for updating the scan is:

STX/U/0/TRM	, to change to very slow scan
STX/U/2/TRM	, to change to normal scan
STX/U/4/TRM	, to change to very fast scan

GAIN - ANALOG, BAR-GRAPH, and LEAK CHECK Modes

The gain data field for all programmable Quadrex 200 displays other than TABLE is a three digit value, where the first digit is the gain multiplier, and the second and third digits are the negative exponents of 10 of the gain value.

The following data fields are valid for changing the gain in any display mode except for the TABLE mode:

Quadrex Display Scale	Data Field in Command Message
0...6, $1x10^{-7}$ amps	307
0...18, $1x10^{-8}$ amps	108
0...6, $1x10^{-8}$ amps	308
0...18, $1x10^{-9}$ amps	109
0...6, $1x10^{-9}$ amps	309
0...18, $1x10^{-10}$ amps	110
0...6, $1x10^{-10}$ amps	310
0...18, $1x10^{-11}$ amps	111
0...6, $1x10^{-11}$ amps	311
0...18, $1x10^{-12}$ amps	112
0...6, $1x10^{-12}$ amps	312
0...18, $1x10^{-13}$ amps	113

The format for updating the amps value of Quadrex 200 in all programmable display modes other than TABLE mode is:

STX/U/three digit value/TRM

TABLE Display Mode Only

For updating the amps value of Quadrex 200 in the TABLE mode, a two-digit number comprises the data field. All table mode gains are $1x10^{-nn}$, where the factor nn is a value 08 through 13. Therefore the format for updating the amps in table mode is:

STX/U/two digit value/TRM

CALIBRATION FACTOR - A one or two digit value. The decimal point is not included in the data field, but is assumed to be located between the two digits given. So, the calibration data field ranges from 1 to 99 (inclusive) corresponding to the Quadrex 200 calibration factors from 0.1 to 9.9.

The format for updating the calibration value of Quadrex 200 in TABLE mode is:

STX/U/one or two digit value/TRM

LOW LIMIT - All Low Limit values must be less than or equal to High Limit values.

HIGH LIMIT - All High Limit values must be greater than or equal to Low Limit values.

For LOW LIMIT and HIGH LIMIT - A three digit value, where a decimal point is assumed to be positioned between the second and the third digits, but is not included in the data field. Valid data fields for limit vary from 000 to 100 with increments of 1 unit, corresponding to Quadrex 200 limit values varying between 00.0 and 10.0.

The format for updating the limit value of the Quadrex 200 in TABLE mode is:

STX/U/three digit value/TRM

CENTER MASS - For the ANALOG and BAR-GRAPH/LIBRARY measurement display modes, this is a 2-digit value ranging from ~~1~~ 5 to ~~90~~ 195 with increments of 1 amu.

The format for updating the center mass value in ANALOG and BAR-GRAPH/LIBRARY mode is:

STX/U/one, two, or three digit value/TRM

MASS NUMBER - A value ranging from 0 to 200 with increments of 1 amu, valid in the TABLE and LEAK CHECK display, the last six masses of the PARTIAL PRESSURE display, and the USER LIBRARY display.

The format for updating the mass number in TABLE mode is:

STX/U/one, two, or three digit value/TRM

PRESSURE UNIT - A one-digit value of 1, 2, or 3 corresponding to Torr, Mbar, or Pascal, respectively.

The format for changing the pressure unit is:

STX/U/one digit value/TRM

SENSITIVITY MANTISSA - A three-digit value in the 9-999 range with an implied decimal point of XX.X.

The format for updating the sensitivity mantissa is:

STX/U/three digit value/TRM

SENSITIVITY EXPONENT - A one-digit value in the 0-9 range corresponding to 10^{-0} through 10^{-9}, respectively.

The format for updating the sensitivity exponent is:

STX/U/one digit value/TRM

FACTOR - A four-digit value in the 1 through 9999 range with an implied decimal point of X.XXX.

The format for changing the factor is:

STX/U/four digit value/TRM

LIB# - A two-digit value in the 0 through 40 range corresponding to the fragmentation pattern.

The format for changing the LIB # is:

STX/U/two digit value/TRM

WIDTH - A one-digit value in the 0 through 6 range corresdponding to a width of 10, 20, 40, 50, 100, or 200, respectively.

The format for changing the width is:

STX/U/one digit value/TRM

VOLUME - A one-digit value in the 0 through 3 range corresponding to OFF, LOW, MEDIUM, and LOUD, respectively.

The format for changing the volume is:

STX/U/one digit value/TRM

NOTE: None of the BAR-SUBTRACT mode parameters are programmable, as well as the six masses and twelve GAINS in the PARTIAL PRESSURE Display.

This UPDATE command always references the Normal, or current, set of displays. The parameter values in the Alternate (stored) set of displays can not be programmed.

Fetch Parameter Pointer

```
Host Command:          STX   F   TRM
Quadrex 200 Response:        Uns  Uns   Ack   4 digit Quadrex 200 Parameter Value    Eot
```

A query is sent to Quadrex 200 for the value of the parameter pointed to by the Parameter Pointer Command. The parameter value transmitted to the host will be either a 1, 2, 3, or 4 digit value with preceding zeros so that all responses are four digits.

Type of Parameter Pointer to	Range of Response (excluding preceding zeros)
Electron Multiplier Voltage	100...300
Scan Speed	0, 1, 2, 3, 4
Amps (Quadrex 200 Table)	108...113
Amps (Quadrex 200 non-table and Partial Pressure displays)	307...113
Calibration	1...99
Limits	0...100
Center Mass	5...195
Mass Number	0...200
Pressure Unit	1, 2, 3

(cont'd)

Type of Parameter Pointer to	Range of Response (excluding preceding zeros)
Sensitivity Mantissa	1...999
Sensitivity Exponent	0...9
Factor	1...9999
Volume	0...3
LIB#	0...40
Width	0...6

The parameter values returned to the host after this command (excluding any preceding zeros) are the same as the acceptable values which may be sent by the host in the UPDATE command with the exception of Table amps.

The response to this command depends on the data set pointed to by either the NORMAL DATA POINTER or ALTERNATE DATA POINTER; and it depends on the parameter previously selected by the PARAMETER POINTER command.

READING QUADREX 200 DATA

There are two basic ways the spectrum data acquired by the Quadrex 200 may be obtained by the host via the RS-232 Interface. The data may be read after it has been updated, as the sweep scans through the programmed mass numbers; or it may be read as it currently exists in the Quadrex 200 memory.

Data is transferred in blocks, which are defined by the INDEX command.

INDEX POINTER COMMAND

Host Command:	STX	I	1st index value...			delimiter	2nd index value...			TRM		
Quadrex 200 Response:		Uns	Uns		Uns...		Uns		Uns...	Ack	Eot	

In commands whose response depend on this command are the GET, TAKE, and PARTIAL PRESSURE READ commands. In all measurement modes, this command is used by the HOST to select the range of data points or channel numbers. In TABLE mode, the command may be used to choose the range of channel numbers whose amplitude values are to be sent; the index values are single digits ranging from 0 to 5 corresponding to channel numbers from 1 to 6 for amplitude data sent with the GET or TAKE commands. In Analog and Leak Check Modes, the command is used to reference a data point range within the 201 data

points in each scan; the index values are each between 0 and 200. In any case, the first index given is less than or equal to the second index given. In the Partial Pressure mode, the command is used to reference the channels 0 through 11.

The delimiter sent between the two mass numbers in the data field is simply any non-numeric character (except for the TRM, STX, CNL, and ESC characters), to separate the two values.

On Quadrex 200 power-on, the default values for the mass number indices of this pointer command are 0,0. This is a valid pair of mass number indices for any of the display modes and points to a single data point in each case.

GET INDEXED DATA ARRAY

```
Host Command:          STX   G   TRM
Quadrex 200 Response:      Uns   Uns   Ack   amplitude of 1st index value,
                      ...,    amplitude of last index value    Eot
```

Either the NORMAL (last measured) or the ALTERNATE (stored) data of Quadrex 200 for the indexed (INDEX command) mass numbers is transferred to the host. When ALTERNATE is pointed to then the Alternate Mode Pointer determines what frozen data is to be transmitted.

The data is sent to the host in the form of: amplitude value of the first channel number, or data point number in the index command, amplitude value of the second data point, and so on until the amplitude value of the last data point or channel number, in the index command is sent, followed by the Eot character.

The amplitude values are transmitted as three-digit values, where a decimal point is implied, but not transmitted, between the second and third digits. For example, a response for a single indexed mass number of 060 corresponds to a peak value of 6.0 (x amps value). There are NO separators sent between the three-digit values, so the data sent will appear as a continuous sequence of digits.

NOTE: This command reads the raw data which is used to calculate the Partial Pressure in the Partial Pressure measurement mode.

TAKE INDEXED ARRAY, SYNCHRONIZED WITH SWEEP

Host Command: STX T TRM
Quadrex 200 Response: Uns Uns Ack amplitude of 1s index value,
..., amplitude of last index value Eot

The real-time amplitude values for each data point or channel included in the INDEX Pointer command are transmitted to the host in this manner: once the Quadrex 200 receives this command from the host, and the scan of the Quadrex 200 returns to the first data point or channel in the current measurement mode, then one entire scan of amplitude values is transmitted to the Interface instead of to the Quadrex 200 screen, and the host receives an indexed set of amplitude values at the time at which Quadrex 200 is reading the amplitude value for each mass number, for those indexed values last selected with the INDEX command.

The amplitude values are transmitted in the form of three digit values, where a decimal point is implied between the second and third digits but is not sent. for example, a single transmission of 200 corresponds to an amplitude value of 10.0 (x amps value). There are NO separators sent between each three-digit value, so the data sent will appear as a continuous sequence of digits.

This command does not depend on the data set currently pointed to by the last ALTERNATE or NORMAL command: it always queries the NORMAL data set.

NOTE: This command gets the raw data when used in the Partial Pressure mode.

Miscellaneous Messages

PARTIAL PRESSURE READ

Host Command: STX L TRM
Quadrex 200 Response: Uns Uns Ack Partial Pressure of 1s index value,
..., Partial Pressure of last index value Eot

This command fetches the Partial Pressure values according to the INDEX command. If more than one channel is selected by the INDEX command, a five-digit value, corresponding to $NX.X\ 10^{-XX}$, is sent for each channel. If ALTERNATE Partial Pressure is selected, the stored Partial Pressure values are sent.

"N" is an ASCII character of 0, 1, 2, or 3.
0 = Bad Partial Pressure data.
1 = Good Partial Pressure data.
2 = Bad Partial Pressure data at end of Gain range.
3 = Good Partial Pressure data at end of Gain range.

LIBRARY SPECTRA READ

```
Host Command:   STX   K   2-digit LIB#    TRM
Quadrex 200 Response:  Uns   Uns   Uns   Uns   Ack   15 ASCII character Name
                  (3-digit Mass number 3-digit % for each of 6 channels)   Eot
```

This command sends a fifteen character Spectra name, followed by a Mass and % of that Spectra. Each Mass is a three-digit value and each % is a three-digit value. There are six sets of Mass and % values.

CANCEL

```
Host Message:   CNL or ctrl-x or 18H or 24 decimal
Quadrex 200 Response:                                   Eot
```

If a communications or command error has occurred, the CNL message clears the Interface of the error, as well as any characters or messages that have been sent after an error has occurred. This command message is used to clear out an Interface error, or to cancel part of any message (except for an escape sequence) that has been sent unintentionally.

This command will not allow the host to cancel a complete message which has already entered processing (Ack character sent by Quadrex 200); and any attempt to send the cancel command at that time results in the Enq character response to the host, without an effect of the cancel, actually setting an error condition.

VERSION QUERY

```
Host Command:          STX   V   TRM
Quadrex 200 Response:        Uns  Uns  Ack   4-digit value    Eot
```

The four digit version value transmitted to the host is the version number which also appears in the lefthand corner of the Quadrex 200 display screen when Quadrex 200 is initially powered to on. The first two digits represent the version number of the Quadrex 200 software (02 or greater), and the last two digits represent the version number of the IEEE Interface software currently installed in Quadrex 200 (50 or greater). .00 indicates no IEEE software/hardware installed. There is an implied decimal point between the first two digits and the last two digits - this decimal point appears on the Quadrex 200 screen, but is not transmitted in this response.

OPTION SWITCH VALUES

```
Host Command:          STX   O   TRM
Quadrex 200 Response:        Uns  Uns  Ack   3-digit options value   Eot
```

The values of all of the six configure switches on the microprocessor board may be obtained by the host with this query command. The values of these switches may only be queried, they are not programmable.

The value returned to the host is a three-digit decimal number ranging from 0 to 063, and is the sum of values denoting the switch positions, as follows.

Switch	Value if Open	Value if Closed
2-1	1	0
2-2	2	0
2-3	4	0
2-4	8	0
2-5	16	0
2-6	32	0

For example, if the Options value received from Quadrex 200 is 19, and since 19 = 1 + 2 + 0 + 0 + 16 + 0, the states of the switches are:

Switch No.	2-1	2-2	2-3	2-4	2-5	2-6
State	open	open	closed	closed	open	closed

For a description of the functions of these switches, refer to the section "Configuring and Adjusting the Quadrex 200" in the Quadrex 200 manual.

PROGRAM EXTRA RELAYS COMMAND

```
Host Command:          STX   R   Data Value(s), 0-14 even...   TRM
Quadrex 200 Response:        Uns  Uns                        Uns...    Ack   Eot
```

This command programs the three extra relays on the Relay I/O board (relays 10, 11 and 12). These relays are closed with an active high input and opened with an active low input. The sum of any of these values is valid data.

Relay Number	J1 Pin Numbers	Value To Open Relay	Value To Close Relay
10	5 and 23	0	2
11	15 and 32	0	4
12	14 and 33	0	8

Message Summary

To Change Status of Quadrex 200 Push Button

Use B command message (Change Status Command)
Use C command message (Push Button Command)

To Query Status of Quadrex 200 Push Button

Use H command message (Status command)
Use S command message (Status command)

To change the Display Screen on Quadrex 200

UNSTORED display: (a measurement mode display)
use M command message (Display Mode Command)

STORED display: (a MEM-X display)
use STX/S/0/TRM command to query status of MEM-X
use STX/B/2/TRM to go to MEM-X or
STX/B/3/TRM to return from MEM-X

To Receive Parameter Value Information

UNSTORED display: (a measurement mode display)
use N command message (Normal Data Pointer)
and P command message (Parameter Pointer Command)
and F command message (Fetch Parameter Command)
use M command message (Display Mode Command)

STORED display: (a stored set of parameters)
use A command message (Alternate Data Pointer)
and P command message (Parameter Pointer Command)
and F command message (Fetch Parameter Command)

Remember BAR-SUBTRACT does not have stored parameters.

To change a Parameter Value at the Quadrex 200

UNSTORED displays only: (a measurement mode display)
use P command message (Parameter Pointer Command)
and U command message (Update Parameter Command

To Receive Quadrex 200 Data

UNSTORED data: (from the current measurement mode display)
use N command message (Normal Data Pointer)
and M command message (Display Mode Command)
and I command message (Index Command)
and either the T command message (Take Command)
or the G command message (Get Command)

STORED data: (from an alternate set of data)
use A command message (Alternate Data Pointer)
and D command message (Alternate Mode Pointer)
and I command message (Index Command)
and G command message (Get Command)

Partial Lockout of the Quadrex 200

There are times when Quadrex 200 is busy processing a command message sent to the Interface. Normally, for most commands sent by the host, this time is insignificant and will not be noticed nor will the time-delay involved be a limitation for the host in its communications with Quadrex 200. However some commands, due to the process involved at Quadrex 200, will take a considerable amount of time to complete.

If Quadrex 200 is busy processing a previously received command, this will be evident to the Quadrex 200 operator by the appearance of a lighted square on the Quadrex 200 screen, which will appear directly to the left of the title "MASS" on most of the display screen (bottom of the screen, near center). Also, all the front panel buttons except for COPY, RELAY, DEGAS, EMULT, EMIS, and POWER, will be inactive when the Quadrex 200 is busy processing a previous command. While this square is lit, indicating command processing is going on, any further command that may be inadvertently sent by the host will cause one or more communication, command errors.

To avoid causing an error (and avoid the necessity of sending a CNL message to clear the Interface of error), the host should allow enough time for the processing of each command. The end of each command is indicated by Eot or Nak. The commands that could take a long time to complete are any of the data retrieval commands (GET and TAKE); the INDEX command when it is pointing to a large interval of mass numbers and/or if the scan speed of the Quadrex 200 is set to Very Slow.

APPENDIX A

Examples of Computer Interfacing to Quadrex 200

A typical flow chart for handling communications between a computer and the Quadrex 200 is shown in Figure 8.4. The specific operations included in each step will depend on the computer, the use to be made of the data, and the action to be taken if errors are detected.

A sample program, written in HP-BASIC for an HP-85F computer is given below. In this program, commands are entered by the operator at the keyboard and data are displayed in raw form. This kind of program is useful in getting familiar with the communications system and can readily be modified to act as a subroutine in a larger program.

```
  1     ! ************************
  2     ! INITIALIZE HOST
  3     ! ************************
 10     CONTROL 10,1 ; 0 ! TURN OFF INTERRUPTS.
 20     CONTROL 10,2 ; 1 ! CLEAR TO SEND.
 30     CONTROL 10,3 ; 15 ! 9600 BAUD.
 40     CONTROL 10,4 ; 26 ! EVEN PARITY, CHAR. LENGTH OF 7.
 50     CONTROL 10,5 ; 48 ! ENABLE RECEIVE AND TRANSMIT
        HANDSHAKE.
 60     CONTROL 10,9 ; 129 ! ENABLE RECEIVER AND TRANSMITTER.
 70     CONTROL 10,16 ; 0 ! NO AUTOMATIC EOL SENT.
 80     DIM O$[20],I$[650],E$[20],C$[20]
 90     IOBUFFER O$
100     IOBUFFER I$
110     IOBUFFER E$
120     ! ^^^^^^^^^^^^^^^^^^^^^^^^
130     ! INPUT AND FORMAT COMMAND
140     ! ************************
150     INPUT C$
160     IF C$="CANCEL" THEN O$=CHR$(24) @ GOTO 190 ! IS A
        CANCEL TO BE SENT?
170     IF C$="ESC" THEN O$=CHR$(27)&C$[4] @ GOTO 190 ! IS AN
        ESCAPE SEQUENCE COMMAND TO BE SENT?
180     O$=CHR$(2)&C$&CHR$(13) ! IF A NORMAL COMMAND TO BE
        SENT, ADD STX AND TRM.
190     !
200     ! *** TRANSMIT COMMAND ***
210     TRANSFER O$ TO 10 INTR
220     TRANSFER 10 TO I$ INTR ; DELIM 4
230     !
240     ! **** CHECK FOR ERRORS AND WAIT FOR ALL RETURNED
        DATA.****
```

```
250     STATUS I$,2 ; T2@ IF T2=0 THEN 310 ! CHECK IF INPUT
        BUFFER HAS RECEIVED ALL DATA.
260     IF POS(I$,CHR$(21))<>0 THEN 360 ! JUMP IF Nak RECEIVED.
270     IF POS(I$,CHR$(5))<>0 THEN 360 ! JUMP IF Enq RECEIVED.
280     GOTO 250 ! KEEP LOOPING.
290     !
300     ! **** COMMAND SUCCESSFULLY SENT, DISPLAY DATA. ****
310     DISP I$
320     CONTROL I$,0 ; 1,0 ! CLEAR SOURCE AND DESTINATION
        POINTERS IN BUFFER.
330     GOTO 140 ! NEXT COMMAND.
340     ! <><><><><><><><><><><><><><><><><>
350     !
360     ! **** ERROR RECEIVED, FIND OUT WHAT IT WAS. ****
370     HALT 10 @ RESUME 10
380     !
390     O$=CHR$(24) ! SEND CANCEL.
400     TRANSFER O$ TO 10 INTR
410     TRANSFER 10 TO E$ INTR; DELIM 4
420     STATUS E$,2 ; T2@ IF T2<>0 THEN 420 ! WAIT UNTIL Eot
        RECEIVED.
430     CONTROL E$,0 ; 1,0 ! CLEAR SOURCE AND DESTINATION
        POINTERS.
440     !
450     O$=CHR$(2)&"SB"&CHR$(13) ! QUERY ERRORS.
460     TRANSFER 0$ TO 10 INTR
470     TRANSFER 10 TO E$ INTR; DELIM 4
480     STATUS E$,2 ; T2@ IF T2<>0 THEN 480 ! WAIT UNTIL Eot
        RECEIVED.
490     DISP E$ ! DISPLAY ERROR.
500     CONTROL E$,0 ; 1,0 ! CLEAR SOURCE AND DESTINATION
        POINTERS.
510     !
520     END
```

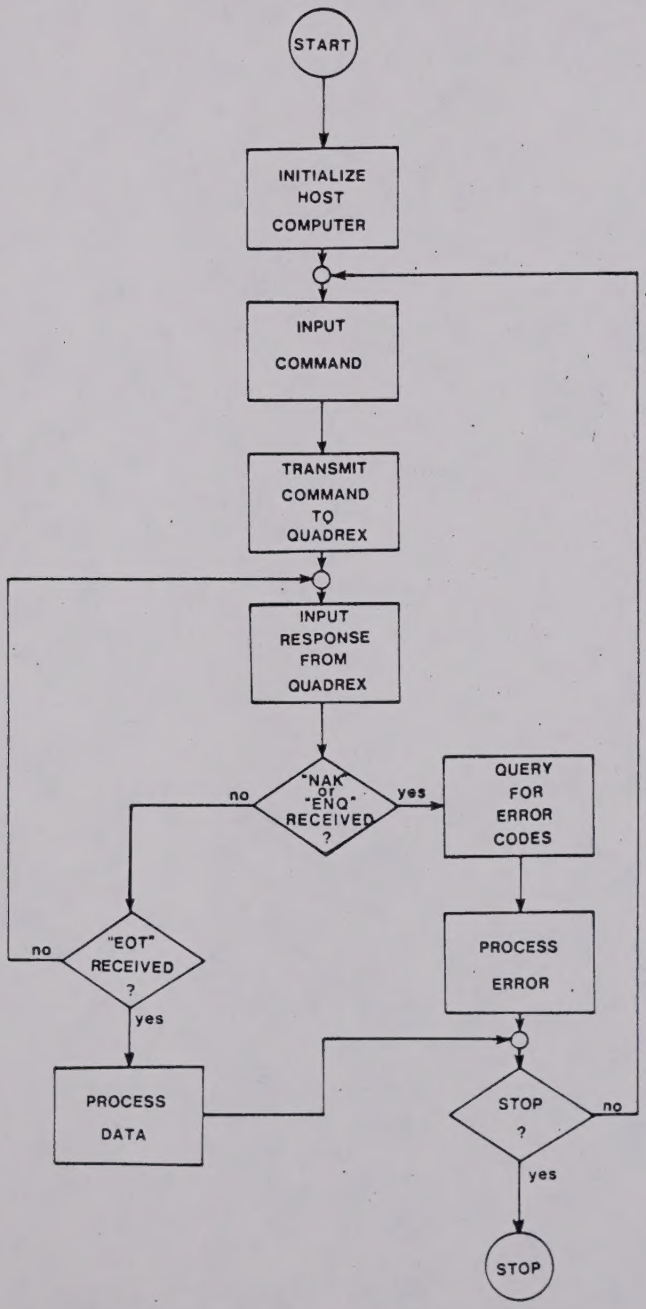
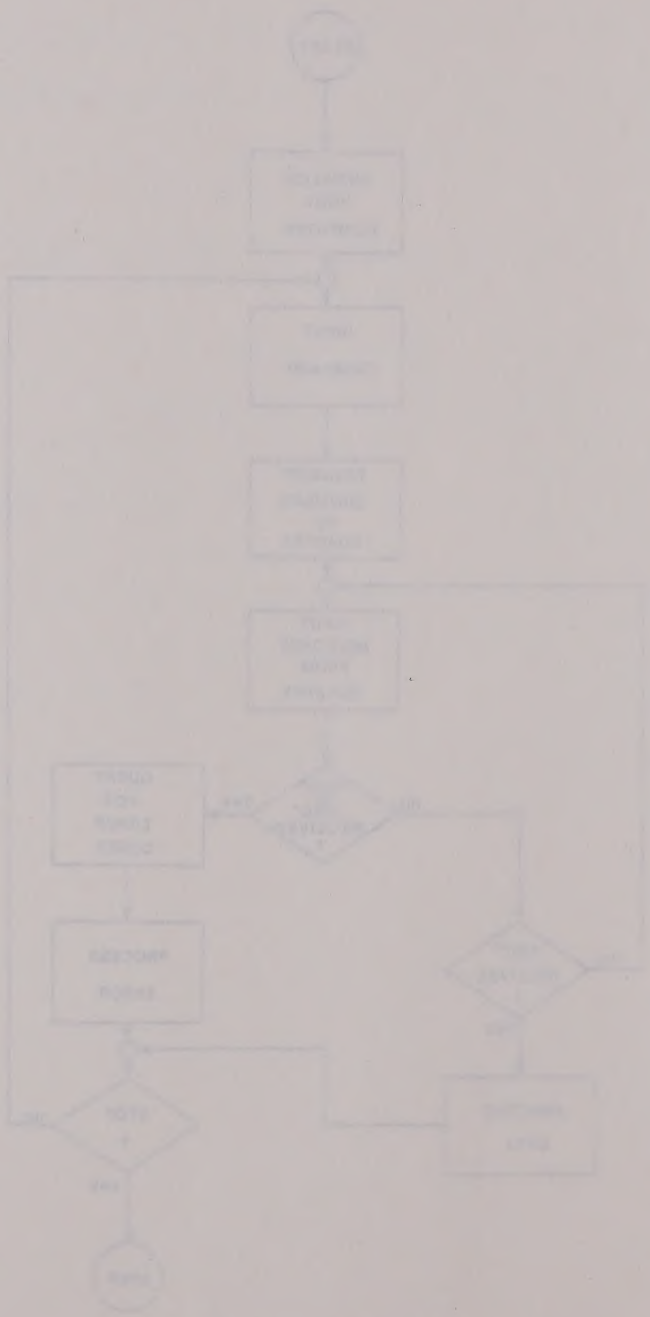


Figure 8.4 Appendix "A" Flow Chart



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